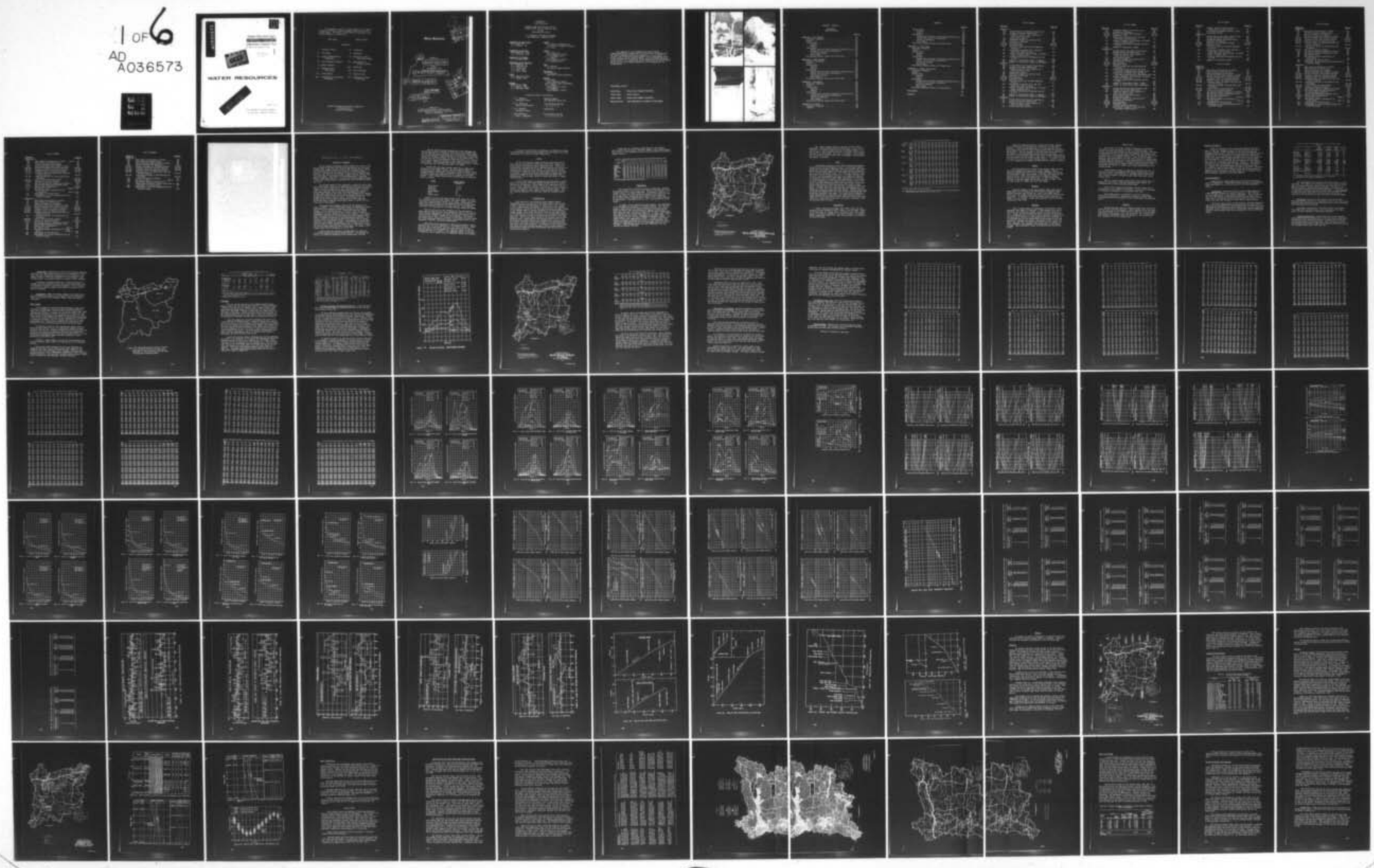
AD-A036 573 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

UNCLASSIFIED NL

1 OF 6
AD A036573



Columbia-North Pacific Region

Comprehensive Framework Study
of Water and Related Lands

APPENDIX V
VOLUME 2

WATER RESOURCES

SUBMITTED BY

PACIFIC NORTHWEST RIVER BASINS COMMISSION
1 COLUMBIA RIVER, VANCOUVER, WASHINGTON

APRIL 1970

This appendix is one of a series making up the complete Columbia-North Pacific Region Framework Study on water and related lands. The results of the study are contained in the several documents as shown below:

Main Report

Summary Report

Appendices

I. History of Study

II. The Region

III. Legal & Administrative Background

IV. Land & Mineral Resources

V. Water Resources

VI. Economic Base & Projections

VII. Flood Control

VIII. Land Measures & Watershed Protection

IX. Irrigation

X. Navigation

XI. Municipal & Industrial Water Supply

XII. Water Quality & Pollution Control

XIII. Recreation

XIV. Fish & Wildlife

XV. Electric Power

XVI. Comprehensive Framework Plans

Pacific Northwest River Basins Commission
1 Columbia River
Vancouver, Washington

Water Resources

APPENDIX V

Columbia-North Pacific Region
Comprehensive Framework Study

Volume 2
[Subregions 7-12]

of Water and Related Lands. Appendix V.
Water Resources. Volume 2. Subregions
7-12,

G. L./Bodhaine, H. D./Hafterson,
M. J./Mundorff John/Summersett

April 1970

512p.

Prepared by
Columbia-North Pacific Technical Staff
Pacific Northwest River Basins Commission
Vancouver, Washington

APPENDIX V
Water Resources

Prepared under the direction of the
Columbia-North Pacific Technical Staff
by the
Hydrology Work Group

G. L. Bodhaine, Chairman (1966-1968)
John Summersett, Chairman (1969)

<u>Department of Agriculture</u>
W. A. Post, FS
D. R. Wagoner, SCS

<u>Department of the Army</u>
John Summersett, Corps
D. M. Rockwood, Corps

<u>Department of Commerce</u>
G. L. Sternes, ESSA

<u>Department of the Interior</u>
G. L. Bodhaine, GS
H. D. Hafterson, BR
F. A. Limpert, BPA
L. A. Reed, FWPCA
C. E. Veirs, FWPCA

<u>Idaho</u>
A. C. Robertson, IWRB
C. E. Tappen, IWRB

<u>Montana</u>
Orrin Ferris, MWRB
A. J. Mancini, MWRB
A. D. McDermott, MWRB

<u>Nevada</u>
E. J. DeRicco, Department of Conservation & Natural Resources
B. J. Vasey, "

<u>Oregon</u>
J. W. Carver, Jr.
State Engineer's Office
P. C. Klingeman, OSU
C. L. Rempel
State Engineer's Office
W. D. Wilkinson, OSU

<u>Utah</u>
E. B. Haycock
Division of Water Resources

<u>Washington</u>
M. E. Garling
Department of Water Resources

<u>Wyoming</u>
F. A. Bishop
State Engineer's Office
Myron Goodson, Water Development
D. L. Simmons
State Engineer's Office
C. E. Tangeman
State Engineer's Office

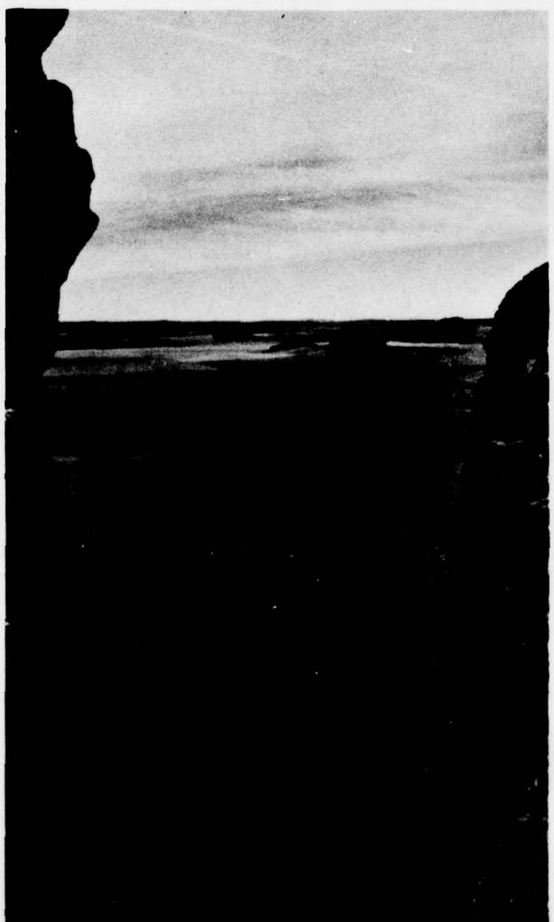
Principal Authors' Contribution

G. L. Bodhaine Geological Survey	Regional Summary One Subregion Section (11)
H. D. Hafterson Bureau of Reclamation	Five Subregion Sections (2, 3, 4, 5, 6)
M. J. Mundorff Geological Survey	Ground Water
John Summersett Corps of Engineers	Six Subregion Sections (1, 7, 8, 9, 10, 12)

This appendix to the Columbia-North Pacific Region Framework Report was prepared at field level under the auspices of the Pacific Northwest River Basins Commission. It is subject to review by the interested Federal agencies at the departmental level, by the Governors of the affected States, and by the Water Resources Council prior to its transmittal to the President of the United States for his review and ultimate transmittal to the Congress for its consideration.

Photography Credits

Ocean Scene	-	**Oregon State Highway Department**
Forest Scene	-	**Forest Service**
Desert Scene	-	**Oregon State Highway Department**
Mountain Scene	-	**Idaho Department of Commerce & Development**



CONTENTS - VOLUME II

APPENDIX V
WATER RESOURCES

CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

SUBREGION 7, MID COLUMBIA

HYDROLOGIC FRAMEWORK

The Mid Columbia Subregion extends between the crests of the Cascade Range on the west and the Blue Mountains on the east, and between lines roughly 30 miles north of the Columbia River (Yakima River Basin Divide) and 140 miles south of it (Central Oregon Plateau). The crest of the Cascades in this area is between 5,000 and 6,500 feet above sea level with a number of peaks several thousand feet higher. The crest of the Blue Mountains is generally between 4,000 and 4,500 feet. At the other extreme, along the banks of the lower Columbia River, elevations are only 100-500 feet above sea level.

The western border of this subregion is about 100 miles from the Pacific Ocean. Between the subregion and the ocean, two mountain ranges - the Coast Range with a crest elevation generally between 1,500 and 2,500 feet and the Cascades mentioned above - extend in north-south parallel lines across both Washington and Oregon. Through these mountains the gorge cut by the Columbia River affords a relatively narrow, nearly sea level passageway between the inland Columbia Basin and the Pacific Ocean. The subregion area is 29,606 square miles, of which 196 square miles are water and 29,440 are land, altogether amounting to about 11 percent of the total area of the region.

The general physiographic features of the subregion are shown in figure 2. To a considerable extent the subregion is characterized by the moderately undulating surface of the Columbia Plateau. In the eastern portion a structural monocline trends northwesterly across Columbia River in the vicinity of Wallula, Washington, and rises above the level of the plateau. Also rising above the plateau level, the Blue Mountains reveal exposed older rocks, including the granite of the Blue Mountain batholith. The plateau consists of Miocene Columbia River basalt and its mantle of gravel, ash, and rhyolitic lavas. Unconformably overlying this basalt in the Cascades are hundreds of feet of later lavas, tuff, and tuff breccia which erupted through vents now marked by a series of volcanic peaks along the crest of the range. Mt. Adams is the highest peak, with an elevation of 12,307 feet.

Runoff from this subregion averaged about 8.1 inches or 177,400 cfs annually during the period 1929-58. The maximum was about 1 2/3 times the average and the minimum about one-half.

The two largest streams originating in the subregion are the Deschutes River, draining the east side of the Cascade Range and the John Day River, draining the Blue Mountains. Stream gradients in the Deschutes range from about 2 to 9 percent in the upper reaches but decrease to about 1/4 percent in the lower valley. In the John Day, the stream gradients range from about 1 to 3 percent in the upper reaches but decrease to less than 1/4 percent in the lower valley. The Deschutes River Basin contributes about 7 inches of runoff per year, the John Day about 3 1/2 inches.

Besides the two large streams, there are six small ones flowing into the Columbia River: the Walla Walla, Umatilla, Klickitat, White Salmon, and Hood Rivers and Willow Creek. Their stream gradients vary widely, estimated at from 1 to 7 percent in the upper reaches and from about 1/5 to 1 percent in the lower valleys. Their average annual runoff contributions in inches are about as follows:

River	Annual Runoff (inches)
Walla Walla	4 1/2
Umatilla	2 1/2
Klickitat	16
White Salmon	41
Hood	44
Willow Creek	1 1/2

Glaciers exist on the upper slopes of Mt. Adams, Mt. Hood, Mt. Jefferson, and the North, Middle, and South Sisters, but cover less than 10 square miles, mostly on Mt. Adams. These glaciers exert only minor influence on the hydrology because of their small extent and relative stability from year to year. They probably contribute less than 200 cfs to stream discharge during the summer.

Most of the soils in the subregion are fine and fertile. Those derived from the basalt and sedimentary rocks in the John Day Basin are more impermeable, but those from the alluvium and loess of the eastern Columbia streams are more permeable. The coarse and porous soils, lavas, and volcanics of the eastern Cascade slopes and Ochoco Mountains absorb and release considerable water in the Deschutes, Klickitat, and White Salmon Basins.

About half of the subregion is covered with forests, largely ponderosa pine but with Douglas-fir in the higher Cascades. There are other firs, scrub pines, and many other varieties of trees. About one-quarter of the subregion is cropland, mostly in dryland farming, but most is irrigable. The remaining quarter of the area is semidesert with a sparse cover of sagebrush, grass, and junipers.

The cities of Walla Walla, Washington, and Pendleton, Oregon, in the northeast corner of the subregion are the largest, with 1960 populations of 24,536 and 14,434, respectively.

CLIMATE

At this latitude most large air masses move from west to east, and in several days' travel across the Pacific Ocean, they have acquired very definite marine characteristics. They have become nearly saturated and their temperatures are close to that of the water over which they have passed. In reaching the inland Columbia Basin, however, these air masses must cross the two mountain ranges. Temperatures of the land surfaces respond much more rapidly to changes in solar heating than does the ocean; and, consequently, they are much colder in winter and warmer in summer than the water.

In the colder months, incoming air from the ocean is cooled both by its contact with colder ground beneath and by its forced ascent over the mountains, which reduces the temperature from 3° to 5°F. for each 1,000-foot increase in elevation. In this cooling process, large quantities of water vapor is precipitated as rain or snow on the middle or upper slopes of the mountain ranges. Thus, air reaching Subregion 7 is much drier than the original marine air.

Precipitation

This area has a very definite winter rainfall regime. Approximately 55 to 65 percent of the annual total occurs in the 5 months, November through March; and only about 8 to 12 percent in the 3 summer months, June-August. Yearly totals rise sharply with increase in elevation, but are much heavier on the upper slopes of the Cascades than at similar elevations in the Blue Mountains. Average annual totals range from 60-80 inches on the upper slopes of the Cascades to less than 9 inches in the Arlington and Umatilla area, then increase to near 35-40 inches at the crest of the Blue Mountains. Only on the higher slopes of the Cascades and the Blue Mountains does a large part of this precipitation occur as snow. On the upper Cascades snowfall is estimated to be as much as 250-350 inches a year and on the higher slopes of the Blue Mountains from 100 to 150 inches annually. In contrast, in the lowest elevation areas the totals average between 12 and 20 inches annually. Table 239 and figure 425 show precipitation data and location of precipitation stations.

Figure 425 is an isohyetal map prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors.

Table 239 - Average Monthly and Annual Precipitation (inches), Mid-Columbia Subregion, 1931-60

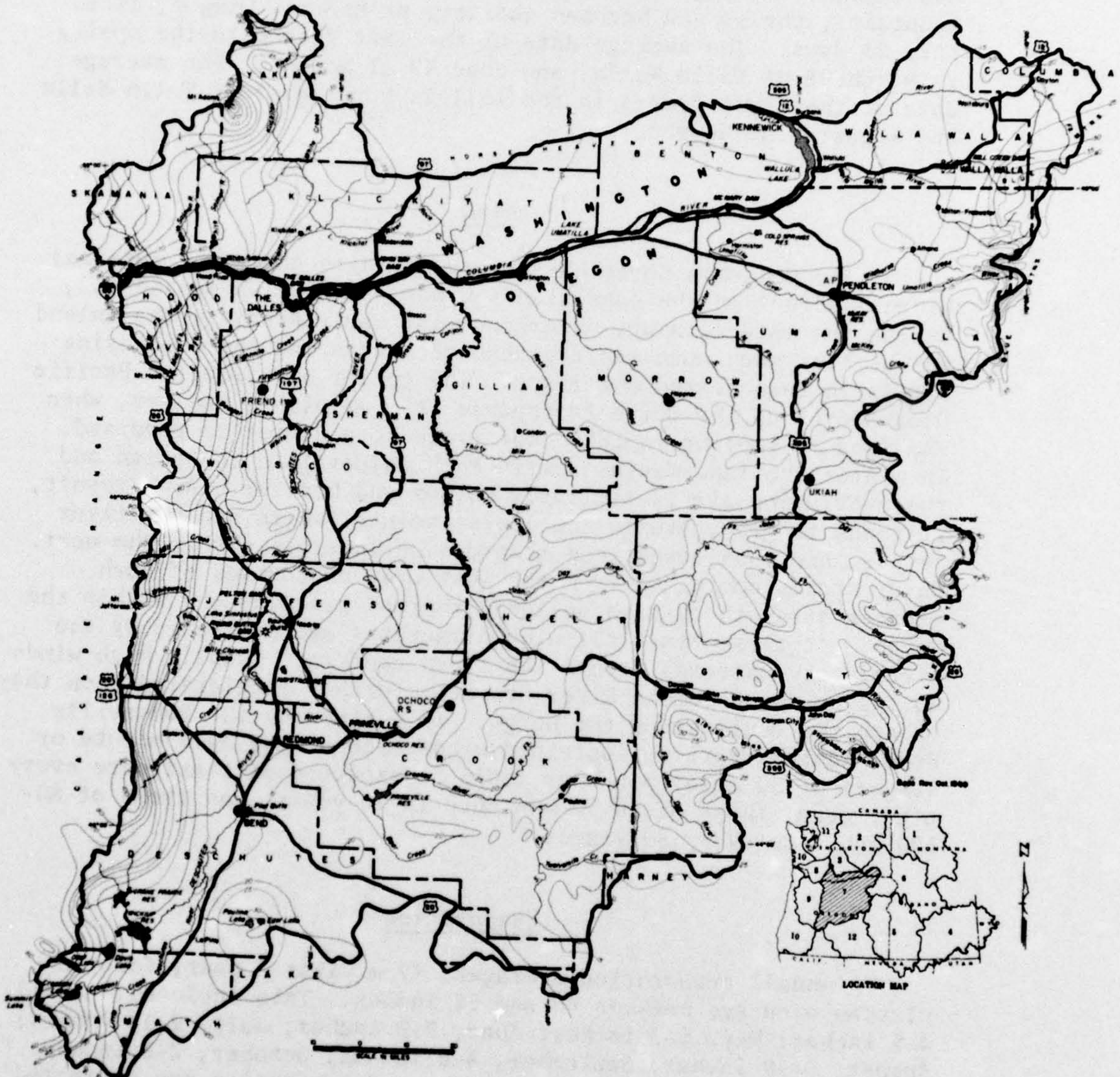
Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Goldendale	1,600	2.93	2.03	1.70	.85	.79	.91	.15	.21	.62	1.64	2.53	3.05	17.41
Arlington	350	1.44	1.01	.84	.49	.56	.65	.14	.16	.33	.85	1.24	1.33	9.04
Pendleton WBAP	1,492	1.42	1.18	1.20	1.09	1.12	1.17	.22	.28	.63	1.18	1.40	1.49	12.38
Heppner	1,950	1.28	1.13	1.29	1.27	1.34	1.40	.32	.38	.73	1.29	1.44	1.38	13.25
Ukiah	3,216	1.91	1.76	1.72	1.52	1.89	1.99	.44	.52	.93	1.50	1.79	2.20	18.17
Dayville 1/	2,364	1.22	1.10	1.00	1.06	1.38	1.20	.42	.46	.60	.83	1.12	1.29	11.68
Ochoco RS 1/	3,979	2.26	1.84	1.64	1.29	1.84	1.78	.61	.60	.79	1.73	2.27	2.65	19.30
Bend	3,599	1.82	1.14	.80	.65	1.12	1.16	.45	.45	.42	.90	1.40	1.73	12.04
Madras	2,244	1.13	.83	.77	.60	1.08	.96	.27	.25	.51	.78	1.14	1.09	9.41
Friend 1 W	2,430	2.91	2.11	1.54	.76	1.06	.99	.21	.17	.60	1.41	2.39	2.73	16.88
The Dalles	102	2.55	1.80	1.37	.53	.62	.66	.08	.16	.47	1.17	2.02	2.36	13.79
Moro	1,868	1.79	1.25	1.08	.76	.84	.88	.17	.17	.50	1.11	1.62	1.64	11.81

1/ Period is longer or shorter than the 30-year normal.

Temperature

Very cold pools of Arctic air form in winter over northern and central Canada. For the most part these are blocked out of the Columbia Basin by the Rocky Mountains. Occasionally, however, an Arctic air mass will break across the mountains and spread out over the Columbia Basin causing the more extreme winter conditions. During these periods, temperatures as low as -25°F. below zero may be experienced. A minimum as low as -54°F. has occurred at Ukiah, Oregon.

In summer, as the ground heats more rapidly, the temperature of the incoming air increases as it moves eastward. Also in this season a high pressure cell may occasionally build up in central Canada as well as over the northern and central Columbia Basin. This large land mass, exposed to long cloudless days, becomes very warm creating a hot, dry air mass above it. At these times temperatures may go well over 100°F. throughout the Columbia Basin. A record high of 119°F. has been recorded at Pendleton, Oregon. The number of days with temperatures of 90°F. or higher varies from 25 days at higher elevations to 40 days at lower locations; the number with temperatures of 32°F. or less range from 65 to nearly 300 days. Table 240 and figure 425 show temperature data and location of weather stations.



EXPLANATION

MEAN ANNUAL PRECIPITATION

● PRECIPITATION STATION

NOTES:

1. ISOHYETAL ANALYSIS PREPARED BY THE U.S. WEATHER BUREAU RIVER FORECAST CENTER, PORTLAND, OREGON, USING ADJUSTED CLIMATOLOGICAL DATA (1930-1957) AND VALUES DERIVED BY CORRELATION WITH PHYSIOGRAPHIC FACTORS.
2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

MID COLUMBIA SUBREGION 7

1968

FIGURE 425

The longest growing season is 218 days at Walla Walla, Washington. Moving south from the Columbia River or up into the mountains, the season becomes shorter; at Madras, Oregon, it is only 51 days. The average date of the last freeze in the spring is March 28 at Walla Walla, and June 17 at Madras. The average date of the first freeze in the fall is November 1 at Walla Walla and August 7 at Madras.

Wind

The Columbia Gorge has a very definite daily and seasonal diurnal effect on the subregion's winds. In the warmer months, during the late morning, afternoon, and early evening, the inland masses heat much more rapidly than the ocean and the overlaying air is in turn heated and rises. The cooler air from the Pacific Ocean moves up the Gorge to replace it. At night, however, when the land is cooling rapidly, the cycle to a degree is reversed. In winter the land masses remain much colder than the ocean and the overlaying air is similarly colder and heavier. As a result, it tends to gravitate to the lowest points, which are the river levels, and then downstream toward even lower levels to the west. Major storms moving in from the west are, of course, of much greater strength than these local thermal circulation's within the Gorge. At those times all wind directions are dominated by the circulatory patterns around the storm centers. Usually high winds moving up the Columbia River are even further accelerated when they escape the confines of the Gorge. In a study by the Bonneville Power Administration, sustained winds (those lasting a minute or longer) of 50 miles per hour could be expected at least once every other year, those of 60-70 mph once in 10 years, and those of 80-100 mph once every 50 years.

Evaporation

Annual evaporation averages, from Class A pans, for the plateau area are between 40 and 55 inches. This includes: April, 4-5 inches; May, 6-7 inches; June, 7-9 inches; July, 9-11 inches; August, 8-10 inches; September, 4-6 inches; October, 2-3 inches. Annual evaporation losses from lakes and reservoirs are estimated at 30 to 45 inches.

Table 240. Average and extreme temperatures (^{o}F), Mid-Columbia Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Goldendale (50)	Av. Max.	36.0	42.7	52.5	61.6	69.4	75.9	85.0	83.4	75.1	63.2	47.5	38.7	60.9
	Av. Min.	22.1	26.4	30.5	34.4	39.7	45.6	50.0	48.4	42.8	36.2	29.9	25.9	36.0
	Mean	29.4	34.6	41.1	48.0	54.7	60.2	66.9	65.1	59.4	49.7	38.5	33.2	48.4
	Highest	61	69	80	91	96	101	109	105	101	88	70	60	109
	Lowest	-29	-28	-3	19	20	30	33	32	19	14	-9	-29	-29
Heppner (68)	Av. Max.	40.4	44.9	53.3	60.9	68.2	75.1	84.6	83.3	74.4	63.7	51.3	42.9	61.9
	Av. Min.	24.4	28.0	32.4	36.3	41.6	47.2	52.3	51.4	45.4	38.5	32.2	27.5	38.1
	Mean	32.3	36.7	42.7	48.8	55.2	61.0	68.1	66.6	60.7	51.6	40.9	36.1	50.1
	Highest	70	72	78	92	100	101	108	110	99	89	80	75	110
	Lowest	-19	-21	-6	9	21	33	36	35	19	10	-8	-18	-21
Dayville 1/ (61)	Av. Max.	42.7	48.4	55.5	64.3	70.7	78.4	88.8	86.7	78.0	66.7	53.0	44.5	64.8
	Av. Min.	24.3	27.7	30.2	34.3	39.8	45.8	49.7	47.6	41.0	34.7	29.7	26.2	35.9
	Mean	33.5	38.0	42.8	49.5	55.3	62.1	69.3	67.2	59.5	50.7	41.4	35.3	50.4
	Highest	68	73	91	95	98	110	111	105	103	98	80	81	111
	Lowest	-32	-22	-2	16	16	29	34	29	16	14	-11	-33	-33
Ochoco RS 1/ (21)	Av. Max.	34.2	39.8	46.4	56.1	64.5	70.7	82.1	80.6	75.1	60.8	44.6	37.5	57.7
	Av. Min.	14.2	19.2	22.2	27.1	32.6	36.7	40.8	38.8	35.2	30.4	24.1	19.9	28.4
	Mean	24.3	29.5	34.4	41.6	48.6	53.8	61.4	59.7	55.2	45.5	34.4	28.7	43.1
	Highest	62	61	73	82	90	96	101	96	100	89	65	68	101
	Lowest	-27	-16	-8	10	13	22	22	21	17	14	-11	-12	-27
Bend (57)	Av. Max.	40.4	44.9	50.9	59.2	66.4	73.4	83.6	82.3	73.7	64.1	50.6	42.2	61.0
	Av. Min.	20.3	23.6	26.1	29.8	35.0	40.4	44.9	43.5	37.7	32.0	27.1	22.9	31.9
	Mean	30.2	33.9	38.3	44.6	50.7	56.4	63.7	62.2	56.3	47.8	38.5	33.3	46.3
	Highest	66	76	83	90	93	100	104	100	98	91	77	69	104
	Lowest	-26	-26	-13	8	11	22	27	25	12	10	-14	-25	-26
Friend 1 W 1/ (16)	Av. Max.	35.6	42.3	48.2	57.6	64.8	71.0	82.7	81.0	74.9	60.7	45.2	39.1	58.6
	Av. Min.	18.8	23.8	26.5	31.0	35.9	39.9	45.0	44.1	40.8	34.1	27.0	23.8	32.6
	Mean	27.2	33.1	37.4	44.1	50.4	55.5	63.9	62.6	57.9	47.4	36.1	31.5	45.6
	Highest	57	62	73	83	89	95	104	102	95	87	65	62	104
	Lowest	-22	-11	-1	16	21	26	28	30	22	15	-9	3	-22
The Dalles (84)	Av. Max.	39.4	46.8	56.8	66.2	73.4	79.5	87.0	86.0	77.9	66.0	50.9	42.5	64.4
	Av. Min.	27.5	30.1	35.8	41.3	47.7	53.9	58.4	57.1	49.8	41.8	34.4	30.5	42.4
	Mean	33.9	39.0	46.4	54.2	61.5	67.4	73.7	72.3	66.0	55.2	42.9	38.0	54.2
	Highest	65	72	82	95	101	105	115	110	107	93	77	74	115
	Lowest	-25	-21	-1	25	30	32	39	41	25	20	-2	-30	-30

1/ Period is longer or shorter than the 30-year normal.

Note: The mean temperature is for the normal period 1931-60; other data are for the period of record through 1960. Numbers under station names denote full years of record for all data.

Potential evapotranspiration is from 20-25 inches annually in the cooler parts of the area and 25-30 inches in the warmer portions. Actual evapotranspiration is used to indicate the computed amount of water lost under existing conditions of temperature and moisture. The low rainfall is the principal limiting factor in the amount of actual evapotranspiration that can take place. In soils of a 2-inch holding capacity the annual average evapotranspiration is between 8 and 10 inches in most areas. It is between 10 and 12 inches for soils with 6-inch holding capacity. For both soils it is 1 to 2 inches more in higher elevations where rainfall is greater.

Storms

The widespread winter storms of the coastal areas also pass over this subregion but generally do little damage. However, localized thunderstorms in the late spring and summer occur often and occasionally cause heavy damage. The flood resulting from the storm of June 4, 1903, on Willow Creek near Heppner, Oregon, resulted in the loss of 247 human lives. A more recent flood occurred in Central Oregon near Mitchell on July 13, 1956. Hail or sleet storms are common and cause some damage.

Humidity

Relative humidity in the early morning hours, when the air temperatures are reaching their lowest point, frequently ranges between 90 percent and 100 percent, even in the summer months. These values are common almost any time of the day in the late fall and winter. In contrast, during the warmest part of the day in summer it is not unusual to have values between 10 and 20 percent, occasionally even lower.

Sunshine

Only a limited amount of information is available in this subregion with regard to cloudiness. There appears to be 100 to 120 clear, 80 to 90 partly cloudy, and 165 to 185 cloudy days a year. Actual sunshine records have never been made at any point in the subregion; but in a study in which records of cloudiness in the area and of sunshine at surrounding points were analyzed, it is estimated that the sun shines about 20-30 percent of the time possible in December and January; increasing to 55-65 percent in April, May, and June; nearing 75-85 percent in July, August, and early September; then gradually decreasing again to the winter average. Fog occasionally occurs in sheltered areas during the winter.

SURFACE WATER

The streams of the Mid Columbia Subregion are variable in flow and use, but the quality of water is generally good. The runoff is mostly from snowmelt in the spring and is highly regulated by upstream reservoirs in the Snake and Columbia River Basins, and by reservoirs in the Deschutes River Basin. The natural flow of the Deschutes River is extremely constant. Flows of the Deschutes, Metolius, and Crooked Rivers are very well sustained by ground water, although some 500 square miles of the Crooked River is considered to be noncontributing semidesert. Although the Walla Walla and Umatilla Rivers are largely fed by snowmelt from the Blue Mountains, both watersheds are subject to intense rain storms during winter on the western slopes.

Flood control storage is comprised of 500,000 acre-feet in John Day Reservoir for regulation of Columbia River floods, 8,200 acre-feet in Mill Creek Reservoir in the Walla Walla River Basin, and a variable amount in Prineville and Ochoco Reservoirs on the Crooked River.

Water is used for power generation on the Columbia River at Bonneville, The Dalles, John Day, and McNary Dams; and on the Deschutes River at Pelton and Round Butte Dams.

Most of the irrigation development that has taken place is concentrated in the Deschutes River Basin. Second to the Deschutes in irrigation development is the Umatilla River Basin.

The Columbia River is intensively used for navigation, fisheries and recreation. Navigation is mostly by large barges and extends beyond the subregion to Pasco, Washington, and Lewiston, Idaho.

Quantity

Average discharge from the subregion totals about 177,400 cfs (128.4 million acre-feet annually). About 163,500 cfs of this flows into the subregion in the Columbia River; 2,300 cfs is lost through evaporation, bank storage, etc.; and 16,200 cfs (11.7 million acre-feet annually) originates within the subregion. The originating flow averages 0.55 cfs per square mile.

Present Utilization

About 18.1 percent of the originating discharge was withdrawn in 1965 for consumptive uses, but only about 6.1 percent was actually consumed. About 3 percent of the water withdrawn for consumptive uses (about 2,940 cfs) was for municipal supplies (56 cfs domestic and 31 cfs industrial); the largest user was irrigation (2,580 cfs), and it was the major consumer (935 cfs of the total of 985 cfs consumed). Self-supplied industry was the second largest user, 258 cfs. Very little flow was used either for steam power generation or for thermal power cooling. However, a vast quantity of water was used for hydroelectric power generation. Recreation is a popular and recognized purpose for most of the reservoirs. All waters are used to some degree for fish and wildlife. Pollution exists in the lower reaches of some streams and causes problems in populated areas tributary to the Walla Walla River, Umatilla River below Pendleton, and Willow Creek near Heppner.

Stream Management

Competition for water among the various users necessitates efficient management. Storage and release, diversions, conservation, legal constraints, etc., all are a part of the water management system.

Impoundments Reservoirs having a total storage capacity of 5,000 acre-feet or more are listed in table 241. Lake Umatilla on the Columbia River is the largest impoundment. Next in order of size are Lake Wallula, Round Butte, Bonneville, and Lake Celilo. There are 17 reservoirs, five of which are multiple-purpose to the extent that they were designed to serve three or more purposes.

The flood control space in Lake Umatilla (John Day Reservoir) may be filled and emptied more than once during the spring flood in smoothing the fluctuations of the Columbia River. On the other hand, the space in Mill Creek Reservoir is filled only during exceptional winter or early spring floods and is evacuated as soon as conditions permit.

Table 241 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More, Subregion 7

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purpose[1/]
Bonneville	Columbia R.	537,000	87,000	20,400	NPR
Clear Lake	Clear Lk.	13,100	11,900	555	IR
Cold Springs	Umatilla R.	45,000[2/]	45,000[2/]	1,550	IR
Crane Prairie	Deschutes R.	55,340	55,300	4,900	IR
Crescent Lake	Crescent Cr.	117,200	86,050	-	IR
Haystack	Haystack Cr.	5,650	5,630	225	I
Lake Umatilla	Columbia R.	2,530,000	530,000	51,000	FNPR
Lake Celilo	Columbia R.	330,000	53,000	11,650	INPR
Lake Wallula	Columbia R.	1,370,000	200,000	38,800	INPR
McKay	McKay Cr.	73,830	73,820	1,280	IR
Mill Creek	Mill Cr.	8,300	7,300	225	F
Ochoco	Ochoco Cr.	48,000	46,500	1,000	IR
Lake Simtustus	Deschutes R.	36,000	3,800	-	P
Prineville	Crooked R.	154,700	152,800	3,000	FIR
Lake Billy Chinook	Deschutes R.	534,700	273,900	4,000	P
Wickiup	Deschutes R.	182,100	182,100	10,600	IR

1/ I-irrigation, F-flood control, N-navigation, P-power, R-recreation.
2/ Reduced about 5,000 acre-feet by sedimentation.

The impoundments have variable short-term effects on river discharge. The changes in discharge due to power loads are abrupt and, on weekends when less power is required, flows may be low. Municipal water is supplied during the summer, principally to satisfy lawn-watering and air-conditioning needs. Irrigation water is supplied at a fairly constant rate from April through September. On the other hand, recreation use requires that the water be retained in the reservoirs as long as possible during the summer.

Diversions Most of the diversions in the Mid Columbia Subregion are for irrigation. The greater part of these are in the Deschutes River Basin, but large diversions also occur in the Walla Walla and Umatilla River Basins.

Any plans to use water in the upper Crooked or Deschutes River Basins must consider that a very large part of the water supply has been committed to downstream irrigation.

Channel Modification Channel modification and revetment construction have been accomplished in the Mill Creek, Walla Walla, and Umatilla River channels and more is planned for the John Day and Deschutes Rivers and Willow Creek. Over 150 miles of other stream improvement work was completed on smaller tributaries within the subregion during 1965, 1966, and 1967.

Forecasting Forecasting is used in flood control operations of reservoirs, flood warning, and to provide a maximum of stored water for power generation, municipal use, and irrigation. The Weather Bureau is officially responsible for providing a flood-warning service to the general public at times of major flooding.

Forecasts of seasonal quantities of water available for storage are made using snow-survey data, precipitation data, data on antecedent conditions, and other parameters. The information is processed by digital computer and updated each month as new data are obtained.

Constraints There are several compacts and treaties that are concerned with runoff in the Columbia River and tributaries. These are discussed in the Regional Summary along with general constraints.

Water Rights

In the segment of the Mid Columbia Subregion lying within the State of Washington, essentially Water Resource Inventory Areas 29-32 (figure 426), a total of 616 active surface-water right appropriation records, in permit and certificate stages, were on file with the Department of Water Resources as of April 30, 1967. Prime rights in this group allow summer period diversions totaling 1,105.14 cfs of which 430.65 cfs is used consumptively, 635.98 cfs is partially consumptive to the resource, and 38.50 cfs is used nonconsumptively. Appropriative supplemental rights have been granted for a total diversion rate of 60.74 cfs in this area.

In addition, a total of 3,683 adjudicated rights, mostly in Water Resource Inventory Area 32, allows prime right diversions totaling 1,883.95 cfs, of which consumptive diversions account for 1,467.45 cfs, partially consumptive diversions are allowed for 415.80 cfs and nonconsumptive diversions are permitted for 0.70 cfs. Adjudicated supplemental rights have been issued for a total diversion rate of 103.13 cfs.

Reservoir storage rights on record for the Washington part of this subregion allow a total of 6,223 acre-feet to be retained annually.

Prime water-right quantities for the more important use categories. and total actual surface-water right quantities are listed in table 242 according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources (Regional Summary). More detailed information about specific rights can be obtained from the Department of Water Resources.

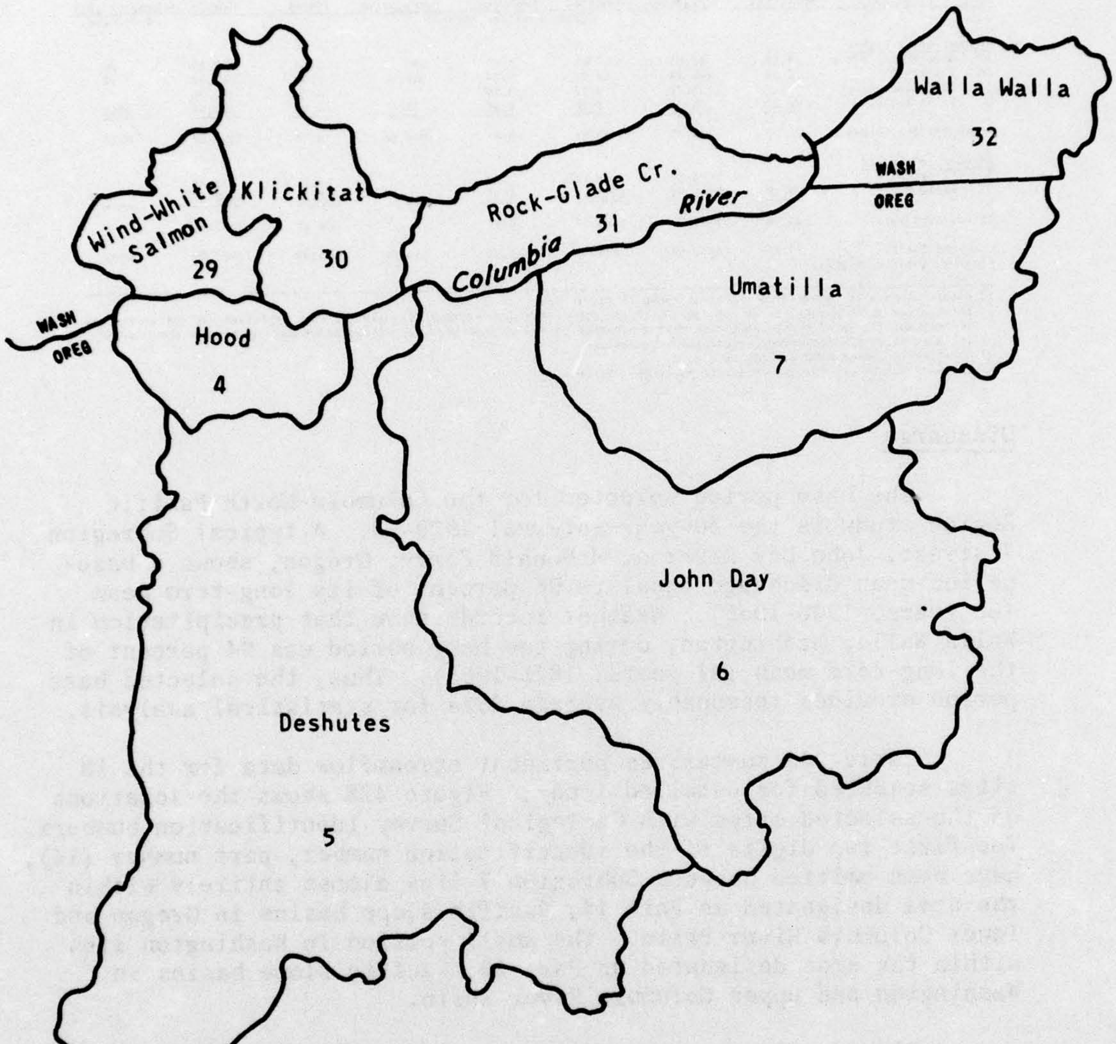


Figure 426 Map showing water resource inventory areas defined by the State of Washington Department of Water Resources and the State of Oregon Water Resources Board.

Table 242 - Surface Water Rights, Washington Portion of the Mid-Columbia Subregion, 1967

Basin No. 1/	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total 2/	Reservoir Storage Rights
		(Cubic Feet per Second)							(Acre-Feet)
Appropriative Rights									
29	Wind White Salmon	4.20	26.03	17.65	1.87	280.29	5.58	367.89 3/	36
30	Klickitat	2.00	155.84	11.04	0.53	304.00	1.24	462.94	24
31	Rock-Glade Creek	-	128.72	0.12	0.50	-	0.30	129.36	-
32	Walla Walla	20.00	79.16	8.16	6.91	34.57	1.89	144.95	6163
Appropriative Totals		26.20	389.75	36.97	9.81	618.86	8.74	1105.14	6223
Adjudicated Rights									
30	Klickitat	-	79.28	69.10 4/	-	-	69.10 4/	79.28	-
32	Walla Walla	23.15	1363.51	1340.17	4.17	-	340.10	1804.67 5/	-
Adjudicated Totals		23.15	1442.79	1409.27	4.17	-	409.20	1883.95	-
Combined Totals (Approp. & Adjud. Rights)		49.35	1832.54	1446.24	13.98	618.86	417.94	2989.09	6223

1/ Water Resource Inventory Area number as shown in figure 426.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed, and (2) water right quantities that are common to two or more uses are listed under each applicable use category.
3/ Includes 41.41 cfs for hydroelectric power generation.
4/ Quantity is common with irrigation use.
5/ Includes 408.50 cfs for hydroelectric power generation.

Discharge

The base period selected for the Columbia-North Pacific Region study is the 30-year interval 1929-58. A typical Subregion 7 stream, John Day River at McDonald Ferry, Oregon, shows a base-period mean discharge equal to 96 percent of its long-term mean (60 years, 1906-1965). Weather records show that precipitation in Walla Walla, Washington, during the base period was 94 percent of the long-term mean (91 years, 1875-1965). Thus, the selected base period provides reasonably average data for statistical analysis.

Table 243 summarizes pertinent streamflow data for the 18 sites selected for detailed study. Figure 428 shows the locations of the selected sites with Geological Survey identification numbers. The first two digits of the identification number, part number (14), have been omitted because Subregion 7 lies almost entirely within the area designated as Part 14, Pacific slope basins in Oregon and lower Columbia River Basin. The small portion in Washington lies within the area designated as Part 12, Pacific slope basins in Washington and upper Columbia River Basin.

Figure 427 presents monthly discharge data for the subregion as a whole. The discharge is the sum of flows generated within the subregion and the inflow to the subregion by the Columbia River, less losses such as evaporation, bank storage, etc. The discharge increases to an intermediate peak in February, mostly due to rainfall, and reaches its yearly peak in May and June, mostly due to snowmelt. The within-area generated flows are also shown in table 244. Isopleths showing mean annual runoff for the period 1931-60 are shown on figure 428.

Table 243. Streamflow Summary for Selected Sites
Subregion 7

Stream	Station	Station Number	Gage Datum	Drainage Area (Sq. Mi.)	Period of Record	Annual Flow 1/ (cfs) Mean	Annual Flow 1/ (cfs) Max.	Annual Flow 1/ (cfs) Min.	Momentary Flow 2/ (cfs) Max.	Momentary Flow 2/ (cfs) Min.
Walla Walla River	Milton	None	--	160	-- -	222	331	136	--	-
Walla Walla River	Touchet	185	405	1,657	1951-65	555	897	237	33,400	2
Umatilla River	Pendleton	210	1067.01	637	1934-65 3/	489	798	286	15,500	10
Umatilla River	Umatilla	335	330.47	2,290	1903-65	420	913	158	19,800	0
Willow Creek	Heppner	345	1952.73	87	1951-65	17	42	3	812 4/	0
John Day River	Picture Gorge	405	2231.84	1,680	1926-65	458	821	124	8,170	1
N.F. John Day River	Monument	460	1959.64	2,520	1925-65	1,217	2,216	484	33,400	6
John Day River	Service Creek	465	1632.42	5,090	1929-65 3/	1,831	3,466	643	40,200	20
John Day River	McDonald Ferry	480	392.27	7,580	1904-65	1,925	3,669	630	42,800	4
Deschutes River	Lava Island	660	3825	1,829	1926-65	1,208	1,789	831	3,360	390
Deschutes River	Bend	705	3503.96	1,899	1914-65	476	718	302	2,820	1
Crooked River	Culver	875	1953.60	4,300	1917-65	1,599	2,066	1,230	8,260	920
Deschutes River	Moody	1030	167.54	10,500	1897-65 3/	5,186	7,340	3,940	75,500	2,400
Columbia River	The Dalles	1057	m.s.l.	237,000	1878-65	171,332	238,583	127,495	1,240,000	35,000
Klickitat River	Pitt	1130	288.9	1,297	1928-65 3/	1,565	2,809	826	31,000	445
Hood River	Hood River 5/	1210	106.37	329	1913-64	1,072	1,684	582	34,000	165
White Salmon	Underwood	1235	112.96	386	1935-65 3/	1,176	1,755	659	9,700	158
Columbia River	Bonneville Dam	1060	m.s.l.	240,000	1938-65	177,400	247,346	131,353	1,240,000	35,000

1/ Regulated values for base period (1929-58) with estimated 1970 conditions of development.
2/ Maximum and minimum observed instantaneous values for period of record.
3/ Denotes other short periods of record prior to dates shown.
4/ Willow Creek flow estimated to have been 36,000 cfs 14 June 1903.
5/ Hood River flows include flow in PP&L conduit.

Average Discharge for Selected Stations In this section of the report, detailed data are presented for each of the selected sites listed in table 243.

The basic monthly discharges for all stations are available in Geological Survey Water-Supply Papers 1316 and 1736 for Washington streams and 1318 and 1738 for Oregon streams, compilations, respectively, of surface-water records in Parts 12 and 14. However, flows for many stations were adjusted for irrigation depletions or storage regulation, and five stations required extension of records by correlation with nearby stations. Since most of the stations required some modification of recorded flows, the values shown in tables 245 to 262 have been termed modified mean discharge, even though some are observed or equivalent discharges. Hydrographs for several conditions of flow at the selected sites are shown on figures 429 to 446. The high, sustained flow is notable for the streams draining the eastern slopes of the Cascade Range. Explanations of these and the succeeding graphs are in the Regional Summary.

It should be pointed out that the supply of water indicated by the monthly discharge hydrographs is not necessarily available for development, even though it already reflects depletions and storage regulation. For example, about 60 percent of the flow shown on figure 438, Deschutes River below Lava Island near Bend, Oregon, has already been committed to irrigation use. This is indicated by the greatly reduced flow at the downstream station Deschutes River below Bend, Oregon, figure 439.

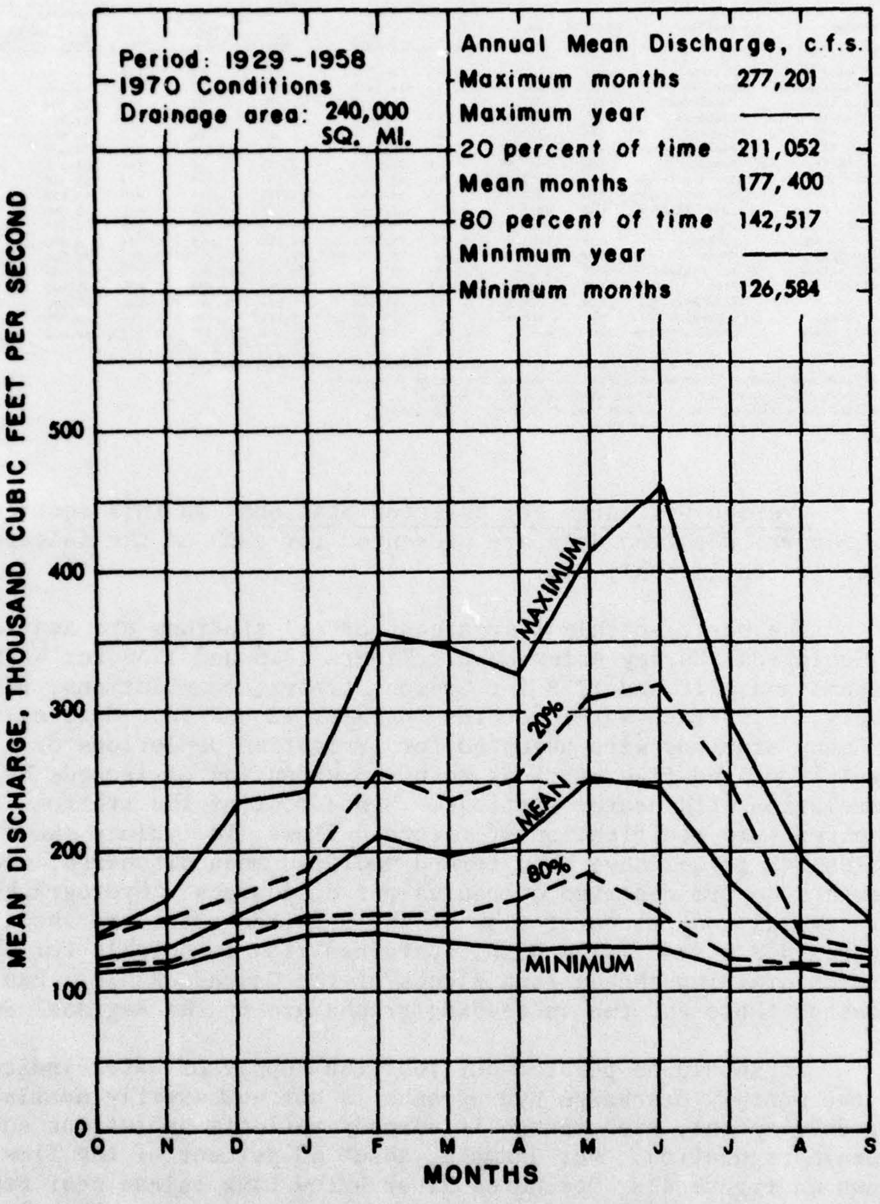
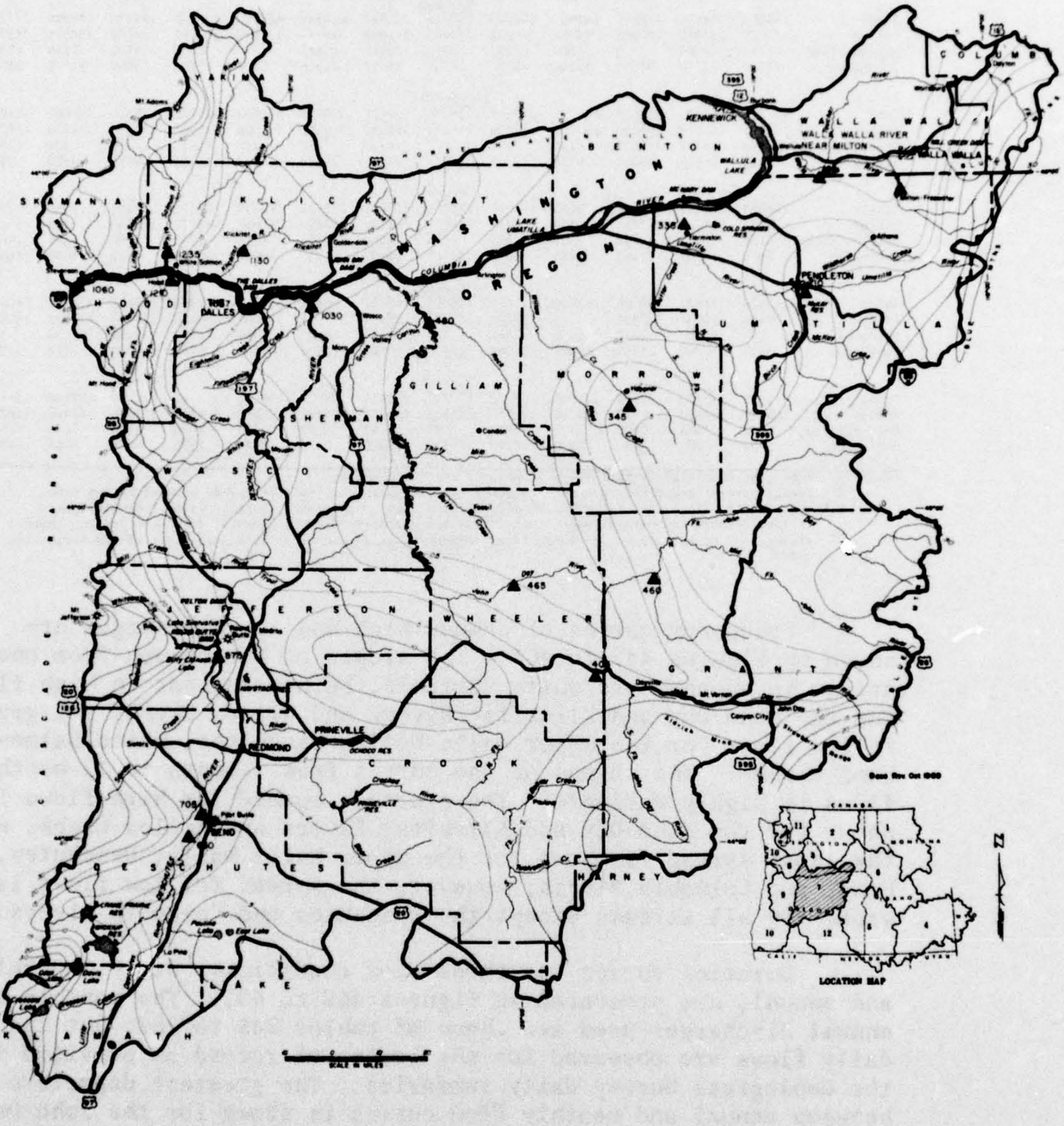


Figure 427 Monthly discharge, Mid-Columbia Subregion



EXPLANATION

MEAN ANNUAL RUNOFF

STREAM GAGE (RECORDING)

NOTES:
1. MEAN ANNUAL RUNOFF ISOPLETHS HAVE BEEN DRAWN BY US GEOLOGICAL SURVEY, USING OBSERVED STREAMFLOW DATA ADJUSTED TO NATURAL CONDITIONS (1951-1960) AND CORRELATED WITH CLIMATOLOGICAL AND PHYSIOGRAPHIC FACTORS.
2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

MID COLUMBIA SUBREGION 7

1968

FIGURE 428

Table 244 Discharge in Mid Columbia Subregion, 1929-58
(Mean discharge in cfs)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean
						Maximum							
Total	143060	164420	235755	243980	356500	345815	326888	413280	459820	290225	196875	149800	277201
Inflow	130732	147016	196995	208494	321233	319443	321339	390541	424349	280763	188176	139826	255742
Unidentified	-1782	-4306	0	-1364	-4273	-8378	-37861	-15531	1	-8338	-4901	-2796	-7461
Subregion	14110	21710	38760	36850	39540	34750	43410	38270	35470	17800	13600	12770	28920
						20 percent							
Total	138026	151520	169059	186725	257457	236079	252472	309048	317860	250025	138260	126094	211052
Inflow	125026	136772	153600	168201	228606	215244	228051	300090	301998	215957	129486	117020	193338
Unidentified	2580	-1392	-10301	-8266	1551	-5975	-7239	-17412	-8388	21018	-1176	-776	-2982
Subregion	10420	16140	25760	26790	27300	26810	31660	26370	24250	13050	9950	9850	20696
						Mean							
Total	124560	131642	154675	175005	211050	198025	207605	252523	245300	175730	130260	122355	177400
Inflow	115080	118176	137785	156370	190217	176971	189248	242090	232637	167070	122450	114286	163531
Unidentified	-158	-43	-508	-320	-481	-715	-6350	-11384	-4237	-2091	-760	-586	-2296
Subregion	9638	13509	17398	18955	21314	21769	24707	21817	16900	10751	8570	8655	16165
						80 percent							
Total	117929	121959	139146	155053	156659	155055	165402	184418	154712	121898	119698	118277	142517
Inflow	109428	110134	125306	136103	139168	137485	152492	179594	143201	114368	114184	111111	131048
Unidentified	281	985	2600	6870	2431	950	-5930	-8876	61	-1190	-2256	56	-335
Subregion	8220	10840	11240	12080	15060	16620	18840	13700	11450	8720	7770	7110	11804
						Minimum							
Total	114885	117150	131270	140345	142470	137140	132655	131975	130785	116110	117130	107100	126584
Inflow	105623	102926	116929	128592	129330	125463	119552	126402	126018	106330	111480	102466	116759
Unidentified	3002	6364	6631	3163	2800	947	-57	-4827	-3573	3950	370	-626	1512
Subregion	6260	7860	7710	8590	10340	10730	13160	10400	8340	5830	5280	5260	8313

NOTES 1. Subregion discharge is that which originates in the subregion.
2. Twenty percent and eighty percent represent the discharge available 20 and 80 percent of the time.
3. Unidentified flows include inflow to main streams from ground water springs, water from atmosphere falling directly on main streams, evaporation and evapotranspiration losses, deep percolation, channel storage and bank storage. Of these items, channel storage accounts for a large part of the variations shown.

Frequency curves of annual high and low discharges are shown on figures 447 to 464. The slopes of the curves from one stream to another are quite variable, being greatest in high flows for the John Day and Klickitat Rivers and Willow Creek, and greatest in low flows for the upper Walla Walla, Deschutes, White Salmon, and Hood Rivers. The spread of the curves from 1-month to 12-month flows is highly variable. The greatest spread for high flows is shown for the John Day and Klickitat Rivers and Willow Creek, while the least spread is shown for the upper Walla Walla, Deschutes, Hood, and Columbia Rivers; however, the spread for low flows is great for all streams except the Deschutes and Columbia Rivers.

Duration curves for three flow conditions, daily, monthly, and annual, are presented in figures 465 to 482. The monthly and annual discharges used are those of tables 245 to 262, but the daily flows are observed for the period of record as provided in the Geological Survey daily summaries. The greatest departure between annual and monthly flow curves is shown for the John Day, Umatilla, and lower Walla Walla Rivers and Willow Creek; while the greatest slope of the curve is exhibited by Willow Creek, the John Day and the Umatilla Rivers.

Frequency curves of annual peak flows are shown in figures 483 to 499. Curves for both regulated and unregulated conditions are presented where flows are modified by reservoirs. The highest degree of regulation is depicted for the upper Deschutes, Crooked, and Columbia Rivers. The curve with greatest slope is that for Willow Creek; other high slopes in order of magnitude are those for the Walla Walla, Umatilla, and Klickitat Rivers.

Dependable yields are given in tables 263 to 280. Each table shows the lowest mean flows for from one to ten consecutive years in the 30-year base period and their relationship to the 30-year mean. The difference between any two flows is a measure of the reservoir storage capacity required to make the higher flow available; Willow Creek near Heppner and the John Day River would require relatively more storage, with the former having a minimum-year flow of only 18 percent of the 30-year mean (table 267). On the other hand, the minimum-year flow of Crooked River near Culver is 77 percent (table 274), and that for the Columbia River is nearly as high. Hood River has the relatively hgihest 10-year average. The average minimum-year discharge for all streams is about 53 percent of the mean.

Variations in Discharge Long-term variations in discharge and precipitation are presented for five streams in figures 500 to 504. The annual means for the base period and for the entire period of record are shown. Although the annual precipitation for a single year varied from the mean by as much as 64 percent, the 5-year moving average varied from the mean by no more than 31 percent.

The 5-year moving averages are presented in order to indicate trends more clearly. Trends for the Deschutes River are masked by the fact that part of its discharge lags the precipitation by several years, particularly that for the Metolius River. Nevertheless, a general decline in precipitation and streamflow is indicated during the period 1895 to 1945, with recovery since then.

As indicated in the discussions on frequency and duration curves, the variation in annual flows at selected sites during the 30-year base period is quite high. The maximum annual discharge is generally about 4.0 times the minimum annual discharge, ranging from 1.7 for the Crooked River to 6.6 for the John Day River at Picture Gorge near Dayville.

Seasonal variations in runoff are clearly shown in the hydrographs in figures 429 to 446. Two annual peaks are shown for all streams except John Day River and Willow Creek, which are almost entirely snowmelt streams. The others indicate varying

importance for the rainfall and snowmelt peaks, with Hood River exhibiting the greatest preponderance of rainfall runoff.

The wide spread in the high-flow frequency curves for the John Day and Klickitat Rivers and Willow Creek, and in the low-flow curves for all streams except the Deschutes and Columbia Rivers, shows great variation from monthly to annual mean discharge. This is confirmed by the departure of monthly duration curve from annual for these streams. The low runoff occurs in August and September, except for that of the Columbia River which occurs in October, and for the upper Deschutes, in November, December, and January. Streams with deep snowpacks, such as the upper Deschutes and Columbia Rivers, or with large underground reservoirs, such as the Deschutes, Klickitat, and White Salmon Rivers, have the smallest variations in seasonal flows. Where low flows are used for irrigation, the remaining low flows exhibit wide seasonal variation such as for the Deschutes River below Bend.

Streamflow Travel Time With the cooperation of Federal and State agencies, time-of-travel studies have been made for the Walla Walla and John Day Rivers. Data for high discharges are lacking. Plots of accumulated time in hours versus river mile for low discharge are shown in figures 505 and 506. The travel time was determined by injections of rhodamine B dye into the river and detecting the leading edge and peak concentration of the dye by fluorometer. The travel rate of the peak concentration of the dye is approximately equal to the average velocity of the water. Travel times in minutes per mile for the lower 10 miles of four rivers under low-flow conditions are as follows: North Fork John Day, 160; John Day, 140; Touchet, 36; Walla Walla, 48.

River Profiles Profiles for selected streams are shown on figures 507 to 509. The profiles were constructed from topographic maps and data from available reports.

(Narrative continued on page 608)

Table 245 - Estimated Mean Discharge, in CFS, Walla Walla River near Milton, Oregon

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										110	93	95	
1929	67	72	73	85	92	303	270	341	214	49	31	38	136
1930	42	46	136	85	380	410	275	260	255	230	210	100	202
1931	91	104	119	179	156	359	381	280	133	83	76	79	170
1932	94	104	140	170	174	514	527	604	308	133	102	101	248
1933	104	234	159	253	146	271	440	514	431	140	114	113	243
1934	120	151	400	321	200	327	240	132	131	107	102	103	194
1935	115	146	207	185	191	227	583	377	198	113	100	98	212
1936	105	105	120	236	142	329	599	421	179	112	103	109	213
1937	104	109	111	99	115	214	355	418	221	112	99	96	171
1938	96	137	233	198	196	323	514	360	175	108	99	97	211
1939	103	140	142	152	174	455	391	348	173	110	90	90	197
1940	96	96	122	145	401	380	430	245	114	95	89	90	192
1941	98	140	186	162	136	164	170	221	222	109	87	96	149
1942	112	177	267	154	204	203	343	294	241	138	88	85	192
1943	92	198	345	243	289	262	595	465	361	155	110	106	268
1944	119	129	142	118	173	264	388	309	167	106	94	95	175
1945	95	101	102	209	251	311	368	542	296	115	100	105	216
1946	99	188	268	238	209	322	438	508	276	139	106	115	242
1947	132	219	516	289	278	305	430	307	178	124	115	120	251
1948	179	352	275	311	297	262	454	818	556	187	139	140	331
1949	140	183	207	147	254	402	534	594	268	144	124	124	260
1950	129	145	161	197	348	405	402	520	501	181	140	133	272
1951	152	274	336	315	355	281	404	359	316	144	128	126	266
1952	186	199	226	173	277	264	572	494	252	182	129	124	256
1953	125	126	129	365	372	336	420	409	307	152	130	124	250
1954	126	144	250	232	276	236	389	311	315	143	125	122	222
1955	124	132	125	141	170	169	309	457	334	145	109	106	193
1956	120	169	362	301	168	283	437	469	225	126	112	107	240
1957	111	130	302	150	266	358	478	529	202	119	106	108	238
1958	124	139	224	244	396	222	528	560	219	127	115	113	251
Mean	113	153	213	203	236	305	422	416	259	131	109	106	222

Table 246 - Modified Mean Discharge, in CFS, Walla Walla River near Touchet, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										9	6	9	
1929	40	25	115	235	260	1220	470	510	172	4	5	5	255
1930	35	20	315	235	1760	1990	480	280	252	150	134	12	472
1931	55	65	255	620	605	1605	965	330	65	4	5	6	382
1932	60	65	335	585	710	2805	1905	1500	355	33	10	12	698
1933	75	535	415	975	550	1015	1295	1150	600	42	20	25	558
1934	125	225	1985	1345	825	1390	360	50	63	10	9	14	533
1935	105	205	655	655	775	770	2415	630	145	10	8	11	532
1936	77	65	265	895	525	1400	2545	790	115	9	10	19	559
1937	75	70	235	275	385	705	825	775	185	9	8	10	296
1938	60	175	795	710	805	1350	1810	575	110	10	8	10	535
1939	75	180	345	495	710	2350	1015	535	105	8	6	8	486
1940	60	45	265	465	1865	1755	1235	240	50	6	5	8	500
1941	65	180	535	545	495	480	145	190	185	10	4	10	237
1942	90	320	1005	505	855	650	770	370	225	40	4	7	403
1943	55	400	1555	935	1285	965	2495	955	462	60	17	16	767
1944	120	140	345	360	705	980	1005	410	100	7	6	10	349
1945	60	55	205	765	1085	1265	905	1260	330	12	9	15	497
1946	67	365	1010	905	875	1340	1285	1130	290	40	14	35	613
1947	170	480	2985	1165	1235	1230	1235	410	115	22	21	42	759
1948	345	960	1055	1285	1335	965	1385	2320	840	100	55	125	897
1949	195	340	655	485	1110	1920	1965	1465	280	47	30	45	711
1950	160	200	425	705	1595	1950	1065	1175	735	92	48	55	684
1951	240	685	1485	1310	1635	1080	1085	575	375	47	34	74	719
1952	397	437	858	1033	1821	973	1520	800	137	94	23	59	679
1953	68	114	280	1540	1494	1153	1071	766	385	35	18	22	579
1954	83	162	909	949	1285	750	969	298	471	41	34	71	502
1955	108	161	272	469	578	498	1129	1048	296	46	12	3	385
1956	144	518	1792	1561	846	1666	1534	1052	189	36	23	49	784
1957	108	205	790	319	1162	1710	1555	1217	142	16	13	20	605
1958	169	174	696	948	1857	717	2160	1147	166	26	7	29	675
Mean	116	252	761	776	1034	1288	1287	799	265	36	20	28	555

Table 247 - Observed Mean Discharge, in CFS, Umatilla River at Pendleton, Oregon

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										47	25	45	
1929	58	80	79	102	164	1190	1080	857	369	55	21	31	341
1930	47	57	107	85	1000	1110	621	274	237	31	20	29	297
1931	72	117	221	435	392	1090	1470	386	89	28	14	29	361
1932	52	147	418	491	667	2470	2020	1340	332	62	30	33	673
1933	49	345	166	521	384	1090	1850	1680	631	77	29	41	572
1934	50	108	886	1057	382	899	452	104	70	22	18	26	341
1935	57	220	579	389	415	441	1400	593	141	45	22	23	359
1936	43	58	82	601	279	1255	2048	668	156	40	26	35	440
1937	42	56	69	70	211	1047	1637	1009	291	65	29	35	380
1938	50	130	473	470	542	1196	1657	491	147	42	25	24	436
1939	43	173	280	327	452	2020	1323	499	133	38	17	24	444
1940	37	52	90	228	1210	1531	1163	325	64	19	19	39	395
1941	55	305	503	441	319	451	299	343	465	130	43	81	286
1942	212	591	759	360	686	634	1095	858	628	189	40	38	505
1943	48	344	1237	823	1257	1020	1957	1046	626	157	46	41	712
1944	61	97	148	94	330	901	1284	502	156	41	26	34	305
1945	45	62	73	432	1183	1163	1413	1230	361	55	29	39	502
1946	46	440	893	751	634	1383	1667	1022	362	92	33	46	614
1947	106	476	1619	683	810	866	951	364	168	52	29	40	512
1948	93	845	818	862	1065	771	1629	2519	740	147	58	48	798
1949	60	147	401	149	1143	1785	2012	1155	238	58	33	40	597
1950	60	121	259	495	1261	1483	1386	1139	807	121	44	39	596
1951	89	424	855	1061	1205	874	1198	609	359	60	31	38	562
1952	201	249	379	312	767	835	1778	894	224	105	33	37	482
1953	44	61	79	1059	1291	1198	1581	923	623	89	40	35	580
1954	51	106	677	460	716	532	986	356	435	82	49	54	372
1955	58	78	81	163	316	427	1157	1667	533	120	34	44	390
1956	68	337	1249	1183	434	1184	1474	1164	259	67	42	41	627
1957	61	105	637	151	928	1539	1667	1210	189	51	35	39	549
1958	75	137	609	753	1695	539	2229	1183	216	56	31	42	621
Mean	68	216	491	500	738	1097	1416	880	335	73	32	38	489

Table 248 - Modified Mean Discharge, in CFS, Umatilla River near Umatilla, Oregon

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										17	14	38	
1929	31	176	130	124	230	1328	723	366	45	25	22	53	271
1930	80	141	131	90	921	829	213	20	29	23	39	22	211
1931	42	59	105	298	219	652	1584	22	28	14	12	13	254
1932	16	42	355	363	525	2736	2469	976	22	19	15	21	630
1933	40	205	179	397	362	787	1396	1576	240	10	16	71	440
1934	54	102	665	1003	328	618	73	11	13	7	11	15	242
1935	22	56	442	333	282	162	852	91	11	16	15	14	191
1936	22	107	100	411	314	1050	1424	153	8	12	10	11	302
1937	11	80	81	102	267	534	1093	326	38	10	27	39	217
1938	55	158	351	314	397	1031	1125	74	28	25	16	21	300
1939	18	140	225	218	334	1475	637	35	19	38	14	13	263
1940	19	140	112	147	935	1378	731	4	15	22	14	15	295
1941	16	243	506	332	142	305	6	31	194	13	41	58	158
1942	229	556	717	565	914	748	963	792	397	145	28	59	509
1943	26	281	1242	1330	1740	1216	1991	891	267	50	64	52	762
1944	130	184	134	109	259	725	941	135	26	23	22	27	226
1945	93	132	137	359	899	981	1249	796	81	27	33	50	403
1946	66	414	816	781	516	1407	1375	468	98	48	46	124	513
1947	152	452	1555	833	799	809	530	15	67	35	24	42	443
1948	88	860	1006	921	1063	973	2052	3236	552	41	57	110	913
1949	150	185	483	277	1590	1887	1795	608	31	20	35	37	592
1950	66	152	204	578	1495	1431	1303	737	785	12	51	56	572
1951	152	374	833	1226	1827	1400	1020	199	140	32	21	26	604
1952	193	242	376	403	868	792	1377	387	23	27	19	32	395
1953	48	102	129	1001	1376	1113	1424	682	397	26	68	76	537
1954	104	160	576	468	694	419	502	13	209	25	35	57	272
1955	53	175	127	127	209	158	666	1323	116	28	45	44	256
1956	51	372	1190	1289	770	1697	1318	1064	44	14	44	24	656
1957	80	205	616	167	838	1404	1350	871	40	12	37	18	470
1958	163	205	649	709	1872	689	2998	936	11	8	46	29	693
Mean	76	223	472	509	766	1024	1173	561	132	27	31	41	420

Table 249 - Observed Mean Discharge, in CFS, Willow Creek at Heppner, Oregon

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										1.5	0.0	0.2	
1929	0.8	4.2	2.4	3.3	5.4	67.0	61.0	41.0	5.0	0.0	0.0	0.0	15.8
1930	0.0	1.7	0.8	0.8	32.0	20.0	7.6	4.1	0.0	0.0	0.0	0.0	5.6
1931	1.3	7.4	0.2	8.1	5.4	6.5	27.0	3.3	0.0	0.0	0.0	0.0	4.9
1932	0.7	0.0	3.3	6.5	31.0	101.0	65.0	37.0	5.5	0.0	0.0	0.0	20.8
1933	1.0	5.0	1.1	0.2	4.5	41.0	50.0	54.0	14.0	0.0	0.0	0.0	14.2
1934	0.0	0.0	0.8	15.0	5.4	4.1	1.7	0.8	10.0	0.0	0.0	0.0	3.2
1935	0.0	0.0	0.8	4.1	9.0	1.6	21.0	9.8	0.0	0.0	0.0	0.0	3.8
1936	0.0	0.0	0.0	1.6	6.3	18.0	29.0	9.8	0.0	0.0	0.0	0.0	5.4
1937	0.0	0.0	0.0	0.0	4.5	49.0	76.0	41.0	3.7	0.0	0.0	0.0	12.0
1938	0.0	0.0	3.3	4.9	13.0	50.0	74.0	22.0	0.7	0.0	0.0	0.0	14.1
1939	0.0	0.0	0.0	0.8	2.7	63.0	18.0	6.5	0.0	0.0	0.0	0.0	7.6
1940	0.0	7.4	0.0	0.8	24.0	35.0	27.0	7.3	0.0	0.0	0.0	0.0	8.5
1941	0.0	0.3	8.1	11.0	9.0	20.0	5.0	14.0	44.0	6.7	0.0	0.0	9.8
1942	2.0	11.0	35.0	43.0	59.0	77.0	82.0	66.0	45.0	3.6	0.0	0.0	35.3
1943	0.8	2.5	50.0	64.0	61.0	48.0	89.0	67.0	33.0	11.0	0.7	0.4	35.6
1944	3.7	8.1	5.7	5.7	7.2	21.0	21.0	15.0	1.7	0.3	0.3	0.2	7.5
1945	1.4	3.8	4.1	6.5	24.0	33.0	45.0	65.0	29.0	0.8	0.4	0.3	17.8
1946	1.2	2.9	15.0	22.0	17.0	48.0	51.0	28.0	9.1	2.3	0.4	0.4	16.4
1947	3.4	8.7	17.0	21.0	45.0	26.0	24.0	8.9	3.9	4.6	0.3	0.3	13.6
1948	4.1	5.0	44.0	35.0	34.0	59.0	103.0	107.0	91.0	20.0	2.0	1.3	42.1
1949	6.2	10.0	6.5	5.7	85.0	79.0	48.0	28.0	1.5	0.2	0.2	0.4	22.6
1950	3.3	7.0	5.7	15.0	64.0	65.0	65.0	56.0	49.0	8.1	0.6	0.4	28.3
1951	4.1	4.9	2.4	36.0	63.0	49.0	57.0	34.0	9.0	1.0	0.3	0.2	21.7
1952	2.9	5.2	6.1	6.4	18.1	24.4	44.4	44.5	10.4	5.5	0.1	0.3	14.0
1953	0.4	2.8	4.5	24.3	39.7	74.5	62.7	52.0	28.8	1.4	0.4	0.4	24.2
1954	1.4	5.3	23.2	13.9	23.0	17.3	34.4	8.0	40.9	2.1	0.5	0.7	14.1
1955	2.6	4.1	3.8	4.3	6.3	12.1	44.9	63.2	16.7	4.3	0.1	0.0	13.6
1956	1.1	11.3	63.0	65.6	36.3	66.4	73.9	67.0	12.4	2.2	0.6	0.3	33.4
1957	2.6	5.7	6.9	5.4	17.1	69.7	72.8	43.2	8.1	0.8	0.1	0.1	19.4
1958	8.3	10.8	29.5	37.7	89.2	52.3	112.0	89.7	14.2	1.1	0.2	0.4	36.7
Mean	1.8	4.5	11.4	15.6	28.0	43.3	49.7	36.4	16.2	2.5	0.2	0.2	17.4

Table 250 -Observed Mean Discharge, in CFS, John Day River at Picture Gorge, near Dayville, Ore.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										88	20	44	
1929	126	163	166	144	136	716	719	715	445	24	4	20	282
1930	98	127	215	135	428	299	220	240	89	10	2	5	154
1931	90	128	132	207	178	339	564	160	78	10	2	4	157
1932	24	100	138	160	284	1592	1404	1187	385	23	6	9	443
1933	60	155	123	151	152	507	964	1140	794	86	12	26	348
1934	79	138	183	250	244	231	146	79	134	13	4	3	124
1935	24	98	178	176	246	247	684	380	169	17	3	3	184
1936	15	94	106	173	259	665	1286	533	212	7	2	4	279
1937	15	75	105	97	150	598	1221	854	382	29	5	6	295
1938	68	191	733	449	644	1176	2060	1204	543	96	31	19	600
1939	99	189	207	187	202	1328	972	401	157	20	4	8	315
1940	45	107	142	233	536	1115	1262	454	133	12	10	56	340
1941	147	241	328	383	461	827	633	938	667	105	107	197	419
1942	210	351	601	532	759	963	1786	1367	800	230	69	59	642
1943	115	295	788	938	1202	1470	2432	1295	885	326	90	73	821
1944	158	250	221	199	246	389	568	342	389	76	21	26	240
1945	87	149	158	240	495	454	1049	1435	694	111	35	41	411
1946	106	235	558	539	501	1145	1635	1088	548	158	25	124	555
1947	174	328	455	350	649	763	930	566	463	61	34	60	400
1948	147	293	452	790	534	591	1572	2955	1899	330	138	132	819
1949	217	240	266	223	732	1189	1502	1146	269	56	32	40	490
1950	156	173	179	264	648	899	1297	900	760	139	50	32	455
1951	192	300	488	566	1328	1130	1775	1150	421	76	22	30	617
1952	192	226	302	266	683	1433	3310	1848	749	188	59	70	774
1953	110	180	197	581	912	879	1438	1630	1465	323	99	88	655
1954	177	274	569	463	868	790	1116	695	597	107	42	81	478
1955	147	187	190	211	215	274	682	1049	568	148	26	29	311
1956	110	227	869	1089	581	1622	2093	1784	805	207	71	79	796
1957	211	276	316	206	692	1500	1675	1553	601	100	51	52	602
1958	278	235	327	504	1787	975	1808	1933	784	205	64	95	741
Mean	123	201	323	357	558	870	1293	1034	563	110	37	49	458

Table 251 - Observed Mean Discharge, in CFS, North Fork John Day River at Monument, Oregon

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										265	96	108	
1929	151	193	150	148	134	1860	2910	3650	1690	289	82	74	948
1930	92	95	228	123	1190	1150	1560	969	659	121	60	60	519
1931	131	116	124	239	286	1400	2960	1490	326	99	37	53	605
1932	89	121	204	378	835	4760	6030	5270	1480	218	72	63	1630
1933	99	191	117	201	167	1400	3610	4510	2810	331	103	92	1140
1934	100	157	601	903	725	1191	1051	378	496	139	42	45	484
1935	93	143	237	284	535	835	2783	2121	744	180	65	50	671
1936	68	92	103	310	357	1419	4071	2323	633	121	46	62	798
1937	58	64	97	76	163	1781	3630	3724	1170	240	71	64	931
1938	103	227	936	649	1064	2725	5331	3033	1059	230	74	64	1289
1939	91	141	226	217	254	3428	3553	1786	519	143	47	51	874
1940	80	84	158	344	1896	3004	3040	1564	375	101	46	84	893
1941	133	372	947	752	898	2056	1793	2330	2026	501	185	264	1021
1942	348	877	1790	940	1658	2389	5517	3933	1809	582	142	100	1661
1943	112	365	1307	1753	2111	3202	6695	4044	2544	840	198	130	1935
1944	157	231	203	184	288	892	1909	1387	695	189	76	74	523
1945	92	125	128	346	1205	1488	3069	4627	1680	273	94	86	1099
1946	106	310	1009	897	786	2726	4447	3552	1320	381	137	147	1320
1947	258	766	1375	693	1693	2145	3034	2170	1228	255	101	115	1147
1948	186	859	1277	1894	1243	1422	4385	8794	5227	830	281	189	2216
1949	227	262	396	248	1664	3666	4604	4673	1103	236	109	111	1439
1950	162	231	251	433	1613	2477	3956	3642	2743	535	164	99	1352
1951	213	573	1132	1387	3032	2393	4919	3415	1010	254	104	89	1530
1952	179	197	340	305	881	2364	5597	5015	1570	483	137	110	1430
1953	98	109	154	1433	1948	2039	3742	4567	3838	859	200	128	1586
1954	144	236	685	559	1508	1405	2739	2152	1980	443	156	133	1005
1955	142	177	131	187	205	429	2116	3444	1962	435	103	101	787
1956	159	467	2729	2485	938	3743	6337	6520	2177	440	173	131	2197
1957	185	222	460	245	1303	3677	4584	5160	1608	274	123	104	1496
1958	317	315	989	1160	4769	2049	5032	6584	2054	480	149	138	1982
Mean	146	277	616	656	1178	2184	3833	3561	1618	350	113	100	1217

Table 252 - Modified Mean Discharge, in CFS, John Day River at Service Creek, Oregon

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										384	95	112	
1929	223	316	314	312	422	2770	3480	4190	1980	330	74	58	1206
1930	170	221	476	278	1720	1490	1900	1220	754	135	62	60	699
1931	202	236	250	479	504	1730	3800	1730	416	97	27	38	790
1932	81	187	316	604	1360	7470	7950	5710	1830	300	76	64	2250
1933	131	348	249	373	366	2010	4970	6090	3890	461	106	106	1590
1934	176	320	813	1288	1036	1438	1263	491	675	161	43	43	643
1935	120	270	468	505	850	1100	3703	2735	992	214	52	31	917
1936	72	192	216	547	721	2406	5699	3139	948	142	46	63	1179
1937	70	152	237	195	358	2651	5523	4998	1664	341	68	60	1363
1938	188	454	1871	1298	1954	4481	7764	4833	1798	372	106	77	2096
1939	198	365	461	453	541	5261	5018	2297	746	185	43	50	1305
1940	125	222	334	604	2452	4463	4729	2098	544	128	44	134	1316
1941	298	589	1280	1141	1367	3063	2623	3480	2868	645	298	492	1512
1942	567	1328	2576	1630	2918	3773	8247	5766	2818	867	220	167	2564
1943	237	661	2338	3244	3828	5109	9812	5900	3798	1295	316	233	3052
1944	361	581	520	428	591	1391	2660	1860	1165	288	86	89	833
1945	169	295	320	624	1890	2062	4352	6358	2607	448	137	131	1611
1946	220	572	1834	1961	1509	4514	6679	5117	2160	596	161	281	2136
1947	455	1213	2149	1026	2743	3299	4403	3253	1850	357	157	178	1747
1948	301	1306	2025	2982	1953	2265	6517	12050	8327	1456	492	281	3329
1949	538	614	823	588	2913	5623	6582	6295	1455	310	144	154	2163
1950	373	459	516	782	2575	3965	5878	4994	3799	774	235	133	2030
1951	422	1003	1859	2280	5141	3863	7403	5109	1568	369	133	121	2416
1952	409	470	742	640	1759	4090	9124	6669	2302	716	206	185	2271
1953	212	305	362	2282	3181	3260	5629	6646	5699	1277	327	250	2441
1954	347	548	1411	1138	2691	2481	4257	3096	2772	580	208	219	1634
1955	302	382	340	437	443	709	3040	4903	2692	647	126	115	1180
1956	282	696	3999	4050	1847	6913	9622	9595	3236	761	260	222	3466
1957	405	563	819	463	2187	5624	6960	7193	2327	436	166	149	2273
1958	636	627	1412	1793	7190	3340	7189	9102	3132	791	224	243	2941
Mean	276	516	1044	1148	1967	3420	5559	4930	2360	516	155	148	1831

Table 253. Modified Mean Discharge, in CFS, John Day River at McDonald Ferry, Oregon

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										433	112	130	
1929	253	352	348	344	459	3055	3810	4605	2206	376	88	71	1330
1930	177	215	497	350	1990	1445	1890	1175	780	151	69	60	733
1931	195	254	264	483	505	1565	3760	1795	476	130	26	31	790
1932	81	226	480	762	1430	7505	7630	6745	1936	334	91	57	2273
1933	127	344	266	378	364	1965	4780	5965	4096	567	121	97	1589
1934	176	331	711	1303	1068	1353	1239	478	632	196	44	30	630
1935	93	269	451	523	862	1028	3604	2655	1091	277	54	35	912
1936	70	193	234	611	994	2487	5318	3212	1000	196	40	55	1201
1937	65	158	220	215	443	2929	5846	5063	1855	417	85	74	1447
1938	193	438	1946	1367	2071	5073	7874	5066	2001	445	124	85	2224
1939	203	382	466	464	524	4881	4976	2460	822	210	37	45	1289
1940	95	206	322	580	2349	4850	5370	2221	641	115	52	128	1411
1941	278	498	1431	1388	1419	3166	2687	3556	3045	750	313	526	1588
1942	567	1463	2813	2025	3847	4185	8364	6006	3143	1035	244	173	2822
1943	250	617	2776	4072	4728	5402	10290	6394	4008	1390	366	266	3380
1944	354	605	531	499	628	1440	2593	1871	1156	335	99	86	850
1945	181	308	354	633	1986	2135	4365	6550	2870	501	148	129	1680
1946	210	498	1782	2325	1367	4789	6512	5001	2138	618	153	271	2139
1947	423	992	2085	1088	2749	3167	4142	3039	1816	414	152	161	1686
1948	318	1259	2185	3269	2350	2722	7083	12445	9537	1853	594	417	3669
1949	627	677	945	657	3146	5947	6429	6173	1620	327	161	149	2238
1950	351	436	557	818	2759	4492	5963	5048	4325	894	267	162	2173
1951	432	1161	2222	2744	5923	4540	7663	5430	1820	422	148	139	2720
1952	391	492	756	685	2025	3970	9281	7032	2614	860	214	193	2376
1953	213	344	401	2461	3511	3355	5491	6890	5893	1381	350	282	2548
1954	391	577	1482	1250	2986	2585	4105	3051	2805	642	204	232	1692
1955	322	422	407	485	500	693	2978	4891	2801	725	132	89	1204
1956	265	615	4461	4953	2409	6376	9316	9599	3583	960	284	280	3592
1957	439	635	846	508	2011	6252	7440	7471	2658	445	180	163	2421
1958	662	672	1486	1947	7828	3827	7365	9131	3380	930	279	265	3148
Mean	280	521	1124	1306	2174	3573	5605	5034	2558	596	170	158	1925

Table 254. Modified Mean Discharges, in CFS, Deschutes River below Lava Island near Bend, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1040	960	1050	
1929	1090	1050	1070	1040	960	1050	1000	1010	1100	1140	1090	966	1050
1930	914	901	1030	910	1060	1000	949	930	1090	1170	931	845	978
1931	857	888	785	770	799	839	856	808	909	899	817	738	831
1932	734	773	753	709	727	853	975	1100	1080	1120	1100	956	907
1933	925	1010	950	949	883	887	998	1050	1360	1260	1410	1170	1070
1934	1115	1139	1118	1126	1055	1037	1098	1008	1154	1280	1247	994	1115
1935	832	827	851	840	850	835	950	1103	1141	1337	1346	1127	1004
1936	974	850	839	899	868	970	1069	1271	1222	1380	1338	1079	1065
1937	995	874	865	861	875	945	1051	1164	1259	1397	1376	1078	1060
1938	907	902	979	981	1123	1222	1315	1594	1415	1452	1516	1379	1233
1939	1243	1251	986	945	934	1050	1134	1247	1311	1420	1301	988	1152
1940	827	816	834	841	914	1007	1016	1060	1200	1210	1016	901	970
1941	852	800	803	781	788	806	739	957	969	1001	856	774	845
1942	737	733	786	747	762	777	806	821	903	1118	996	838	836
1943	762	791	1021	1039	1041	1076	1433	1370	1435	1349	1497	1590	1200
1944	1398	1495	1272	1209	1145	1065	881	1106	1206	1335	1248	1114	1207
1945	848	654	656	676	685	615	815	975	1063	1340	1344	1162	904
1946	1089	883	709	805	691	767	867	1432	1488	1571	1739	1687	1147
1947	1495	990	914	779	852	937	1124	1404	1385	1670	1529	1321	1203
1948	1148	589	625	577	546	543	809	1235	1429	1971	1835	1823	1096
1949	1200	556	539	516	576	681	1044	1804	1953	2161	1916	1731	1227
1950	995	554	555	546	697	1042	1274	1945	2096	2396	2343	2102	1381
1951	1158	845	1005	1033	1575	1530	1761	2003	2283	2460	2456	2104	1685
1952	1763	1148	838	768	855	1345	1966	2226	2721	2657	2540	2034	1741
1953	1592	721	661	844	1086	1036	1380	1969	1913	2537	2370	1962	1509
1954	1368	1002	1175	1293	1431	1418	1731	2276	2048	2546	2256	1760	1695
1955	1088	740	781	974	1106	1247	1413	1784	2323	2308	2298	1781	1489
1956	1234	716	915	975	787	846	1610	2313	2328	2625	2445	2217	1587
1957	1338	998	1025	1052	1369	1820	1745	2016	2473	2607	2423	2063	1789
1958	1121	794	810	818	1242	1255	1359	2296	2184	2487	2450	2013	1572
Mean	1090	876	868	877	939	1020	1170	1440	1550	1710	1600	1350	1208

Table 255. Modified Mean Discharges, in CFS, Deschutes River below Bend, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										146	173	241	
1929	411	1030	1010	1010	897	924	556	153	135	138	120	163	544
1930	304	669	949	800	933	907	231	174	169	139	71	147	456
1931	183	785	696	652	662	564	292	135	110	68	11	35	356
1932	129	532	638	673	589	627	386	224	157	158	109	133	362
1933	189	837	957	915	787	758	431	126	298	168	135	154	478
1934	163	945	1049	1015	748	562	197	96	123	102	106	108	433
1935	248	713	794	801	775	734	413	190	112	163	106	104	428
1936	129	799	795	895	872	921	571	331	185	121	167	146	493
1937	107	562	843	901	827	880	801	146	141	116	112	112	460
1938	218	582	852	905	1042	1138	992	491	228	139	167	227	579
1939	536	1034	974	863	907	990	182	105	104	104	96	98	498
1940	99	429	790	856	903	979	411	112	107	74	21	99	406
1941	162	543	742	734	713	693	129	75	30	21	21	98	328
1942	108	400	714	694	708	764	187	66	23	23	20	20	309
1943	55	357	948	1034	925	997	827	424	365	412	257	391	581
1944	588	1194	1186	1197	1068	1004	348	132	142	67	56	119	591
1945	198	422	578	596	602	489	207	95	60	105	117	167	302
1946	276	501	528	693	579	606	282	175	75	35	152	444	361
1947	760	760	773	713	784	867	283	53	109	71	59	74	441
1948	248	344	584	573	454	363	214	105	269	105	150	404	317
1949	628	323	532	523	518	574	362	72	53	58	76	151	322
1950	196	289	548	557	621	995	281	136	588	90	349	405	420
1951	416	695	938	994	1495	1439	666	305	167	193	570	523	696
1952	855	1062	804	749	788	1276	686	255	799	389	486	482	718
1953	225	637	539	768	1069	957	357	307	328	131	393	397	505
1954	332	938	1068	1207	1386	1402	544	249	383	201	258	308	686
1955	188	649	703	895	1032	665	150	155	120	89	45	94	395
1956	102	658	846	940	732	788	608	586	403	121	169	318	522
1957	581	948	960	1076	1339	1767	918	300	116	106	122	138	694
1958	520	700	615	782	1226	1205	312	191	301	128	117	205	521
Mean	305	678	802	834	866	898	427	199	207	128	155	208	476

Table 256. Modified Mean Discharges, in CFS, Crooked River near Culver, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1140	1100	1140	
1929	1200	1180	1170	1170	1170	1590	1700	1360	1200	1130	1130	1150	1260
1930	1160	1210	1320	1250	1690	1440	1320	1220	1190	1190	1170	1170	1280
1931	1170	1170	1170	1190	1260	1460	1660	1180	1140	1140	1140	1140	1230
1932	1150	1190	1210	1230	1370	2740	2590	1750	1240	1170	1170	1180	1500
1933	1190	1240	1260	1250	1260	1440	2250	1720	1310	1190	1180	1200	1370
1934	1225	1250	1273	1350	1318	1294	1204	1188	1191	1180	1180	1180	1236
1935	1180	1183	1251	1280	1338	1415	2321	1472	1202	1215	1188	1191	1352
1936	1210	1239	1258	1325	1511	1961	2888	1423	1258	1180	1169	1211	1467
1937	1200	1198	1220	1216	1250	1590	2674	1737	1300	1195	1169	1216	1413
1938	1232	1315	1753	1428	1624	2659	4299	2079	1319	1194	1197	1228	1776
1939	1276	1290	1261	1256	1277	2204	1821	1185	1150	1146	1148	1185	1350
1940	1234	1263	1269	1317	1706	2798	2302	1339	1186	1170	1173	1222	1497
1941	1291	1314	1359	1386	1510	2468	1913	1451	1312	1208	1225	1290	1477
1942	1301	1425	1544	1472	1815	2054	3162	1746	1457	1243	1190	1235	1634
1943	1228	1394	1829	2241	2393	3387	4348	2105	1506	1293	1251	1270	2016
1944	1349	1399	1338	1304	1394	1701	1763	1280	1296	1213	1199	1234	1372
1945	1273	1311	1321	1527	1931	1645	2561	2122	1559	1243	1220	1276	1579
1946	1315	1428	1863	2053	1800	2935	3662	1911	1432	1368	1343	1431	1878
1947	1439	1521	1592	1415	1727	1880	1741	1320	1409	1302	1323	1341	1499
1948	1393	1421	1452	1706	1692	1658	2798	2817	2464	1431	1351	1369	1793
1949	1412	1468	1434	1380	2182	2745	3011	1905	1343	1290	1333	1390	1737
1950	1380	1383	1374	1375	1767	2071	2748	1843	1720	1313	1313	1338	1633
1951	1373	1494	1970	1691	2991	2600	3305	2213	1353	1293	1316	1344	1903
1952	1415	1394	1483	1425	1894	2718	4820	1988	1491	1361	1355	1398	1891
1953	1409	1418	1396	2003	2362	2184	3174	2547	2149	1491	1411	1435	1910
1954	1468	1522	1796	1599	2181	2286	2408	1578	1553	1376	1413	1435	1714
1955	1460	1417	1409	1416	1412	1510	1894	2068	1405	1382	1344	1442	1514
1956	1469	1484	2197	2326	1784	3178	3434	2966	1640	1436	1413	1434	2066
1957	1546	1513	1527	1433	2030	2723	2881	2001	1426	1372	1365	1369	1763
1958	1520	1446	1534	1651	3977	3490	3428	2412	1707	1421	1375	1426	2017
Mean	1320	1350	1460	1470	1790	2190	2670	1720	1430	1270	1260	1260	1599

Table 257. Modified Mean Discharges, in CFS, Deschutes River at Moody near Biggs, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										4806	4596	4562	
1929	3980	4260	4110	5390	4250	4750	4490	5140	4780	4430	3550	3760	4410
1930	3780	3680	4590	5170	5980	4260	4250	4000	3830	3520	3620	3820	4210
1931	3690	3810	3690	5050	3820	4080	5450	4420	3920	3050	3050	3190	3940
1932	3400	3430	3700	6580	6410	6200	5130	5320	4520	3440	3360	3430	4580
1933	3460	3790	4210	5100	4370	4270	4770	5190	6510	4850	3980	3880	4530
1934	3600	3960	5880	6350	4820	4780	4240	4280	4000	3970	3680	3660	4440
1935	4040	4390	5150	5700	4920	4360	5050	5460	4940	4550	3720	3850	4680
1936	3800	3990	4000	6490	4800	4750	6240	5555	4890	4220	3993	4000	4730
1937	3650	3640	4010	5310	4160	4660	6160	5280	5120	4240	3870	3970	4510
1938	3900	4380	5820	7510	6450	7310	9320	6710	5010	4270	4080	4010	5730
1939	3790	4320	4600	5530	4530	4680	4850	4460	3980	3450	3790	3850	4320
1940	3750	3570	4050	5300	5350	5680	5170	4060	3830	3540	3150	3700	4260
1941	3740	3760	4130	5600	4510	4183	4140	4130	4240	3130	3340	3570	4040
1942	3500	3850	5160	5810	6350	4520	5400	4680	4534	3420	3350	3590	4510
1943	3630	4960	8120	9970	9650	6860	10500	6920	5840	5330	4410	3990	6680
1944	3780	4001	4092	6130	5860	5530	5540	4350	4000	3410	3620	3560	4490
1945	3420	3620	3870	6270	6340	5530	5660	5160	4320	3400	3390	3450	4540
1946	3470	3590	4500	8350	5550	5770	7300	6390	5340	4670	4090	4180	5270
1947	4180	4980	7920	5710	6370	5420	4890	4650	4560	4140	3870	3930	5050
1948	3448	4610	4750	6640	5960	5090	5870	7430	7840	4790	4230	4420	5420
1949	4700	4180	5150	5390	7840	7100	7740	8400	5933	4780	4320	4350	5820
1950	4230	4180	4480	5180	7180	6780	7190	7040	8020	5460	4780	4730	5770
1951	5100	6170	8020	8740	11820	8560	8610	7850	5640	4920	4890	4870	7100
1952	5350	5320	5500	5740	6980	6090	7770	7170	6520	5410	4870	4840	5960
1953	4310	4340	4410	9600	9180	5420	6760	7420	6960	5300	4910	4830	6120
1954	4630	5290	7200	8290	9220	7140	6960	6730	6370	5240	4810	4820	6390
1955	4730	4730	4720	5840	5260	4230	4670	5730	6740	5200	4510	4540	5080
1956	4580	5530	9770	10870	7250	8260	9014	10040	7380	5350	4960	5040	7340
1957	5150	5190	5930	6050	6320	8230	7940	7170	5210	4790	4720	4850	5960
1958	4960	4660	4980	6980	11280	6470	7670	7290	6410	4570	4280	4160	6140
Mean	4060	4340	5220	6550	6420	5600	6230	5950	5370	4360	4040	4090	5186

Table 258. Modified Mean Discharges, in CFS, Columbia River at The Dalles, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										248755	125645	110824	
1929	111951	118397	132743	141588	155300	140700	134560	123674	129451	113140	115281	116084	127728
1930	114898	121584	138691	140207	154300	133600	126054	129573	128885	113410	115609	113180	127495
1931	116654	119238	137713	137360	139100	139400	144584	132386	131766	117709	115289	105201	128033
1932	113655	119720	136186	149755	143800	166900	173919	266378	248153	117648	119493	121433	156415
1933	122409	116664	140965	180883	223300	164900	181911	271848	339956	219630	151007	134434	187317
1934	138859	159818	210756	226182	283400	274100	318289	290135	205443	130248	121234	121742	206679
1935	110943	114908	149937	175923	190900	160400	169030	218567	228766	161713	124922	119418	160448
1936	119544	122463	138992	170074	139600	150300	157818	267781	195727	115779	118979	118026	151249
1937	117721	123202	136385	142567	148300	138100	132369	135242	129708	116852	121188	118561	130011
1938	116225	112179	135560	170955	197400	179100	207332	242656	256041	208618	121514	117239	172057
1939	119395	119001	129262	167653	138100	156300	175443	184593	158058	121879	121409	119420	142536
1940	115940	123385	126158	176351	164200	175700	180494	177718	151112	121003	123514	120162	146308
1941	117337	125248	137646	149363	151300	149900	180252	146175	152572	123179	120712	119322	139404
1942	125651	125456	155966	169562	197800	154400	193316	197048	230255	141224	125192	121584	161449
1943	119410	112362	142051	178465	250400	226100	270957	353047	242629	211814	129591	117981	196224
1944	114533	119733	132367	136693	158700	133000	139805	138520	141686	119698	116614	108281	129967
1945	115939	121974	135255	142882	147300	137700	137743	190708	146800	122523	122828	118417	136667
1946	120222	117849	132057	159087	189500	193800	210575	271968	254408	177607	121565	124000	172716
1947	121193	132624	174009	173474	222900	225100	221533	297534	250202	177446	118781	114698	175683
1948	132426	152455	168434	178003	284900	257700	231736	328172	452420	254601	151524	134377	227226
1949	126276	127883	136867	174404	202100	194900	211078	297148	274422	115619	116998	115526	174428
1950	113756	112188	148323	173795	248200	263600	243959	295487	329791	284724	141785	128184	206973
1951	135728	150445	164483	180776	342300	299600	310676	292024	262598	221012	142438	122657	218722
1952	136118	145920	160939	177848	239100	209700	243522	333867	257070	196552	116470	116177	194438
1953	117501	121412	137435	167572	214500	164300	175114	267603	294185	194159	126363	119908	175000
1954	120549	131920	157214	176104	239500	225100	194068	281561	310660	283607	193776	147246	205098
1955	135429	147447	161703	177176	197400	146500	159052	184656	281648	245325	135339	119879	174289
1956	134439	149614	177483	188646	288900	336000	295063	400182	381797	251443	134660	124923	238583
1957	127855	130742	162154	180584	222800	213600	217344	318684	324043	161397	115504	117085	190977
1958	116627	117726	127081	172888	226100	196600	233264	295677	284780	219073	131313	105105	185514
Mean	121640	127117	147490	167890	203400	190200	199030	244350	239167	171950	127690	120000	1713[illegible]

Table 259. Modified Mean Discharges. in CFS, Klickitat River near Pitt, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							2193	2075	1844	1069	740	861	
1929	796	799	759	729	898	1374	1332	2066	1668	926	706	638	1062
1930	615	577	747	626	2184	1304	1782	1346	998	748	620	688	1002
1931	574	569	529	673	727	1074	2112	1766	931	641	558	558	892
1932	582	641	676	1264	1694	3024	2392	2676	1908	1086	782	684	1452
1933	666	1184	1188	1384	1154	2024	2732	2816	3448	1636	931	780	1662
1934	949	1019	6168	5604	2387	2382	2342	1542	1145	949	856	777	2185
1935	935	1672	1882	2115	1983	1744	1952	2547	1939	1110	850	773	1624
1936	729	711	703	1822	951	1788	2257	2678	1838	947	719	688	1321
1937	659	607	674	611	850	1749	2348	2376	2150	1084	626	601	1195
1938	625	1038	2388	3136	2017	3668	3562	3636	2508	1324	917	845	2142
1939	792	778	863	839	1120	1350	1685	1726	1085	780	631	612	1021
1940	597	575	823	786	2498	2603	2153	1969	1104	735	643	622	1255
1941	644	680	940	1248	1350	1459	1643	1361	887	674	572	600	1003
1942	635	729	1595	900	2089	1273	1792	1646	1223	782	629	573	1149
1943	560	1003	1881	1939	2738	2569	4934	3004	2549	1469	903	803	2021
1944	810	813	825	764	931	925	1054	1219	891	618	518	543	826
1945	519	535	570	748	1127	948	1261	2174	1292	713	557	593	923
1946	550	731	1473	2128	1717	2289	2294	3371	2242	1375	784	678	1637
1947	722	1086	2382	1238	2358	2107	2090	2406	1552	968	710	715	1523
1948	1219	1215	1097	2359	2140	1989	2068	3193	3146	1307	856	729	1775
1949	843	876	1212	695	2467	3558	3262	4015	2402	1270	898	840	1857
1950	832	1127	1053	1110	2508	3652	3243	3378	3409	1784	1035	848	1993
1951	1087	1870	3981	3804	4845	2862	4153	3933	2384	1298	941	890	2659
1952	1127	1130	1708	1101	3356	1910	3165	3018	1867	1172	861	772	1760
1953	762	780	839	4214	3254	1667	1935	2837	2163	1341	828	742	1775
1954	765	884	1518	1760	2945	2783	3390	3324	2587	1789	1001	868	1963
1955	922	1061	944	936	939	1022	1470	2001	2507	1291	840	757	1224
1956	990	1839	4239	3777	1944	3034	4918	5211	3563	1919	1168	1021	2809
1957	921	929	1183	871	1218	2734	2490	2902	1486	923	729	705	1429
1958	814	780	1212	2076	3893	2040	2353	3350	1896	1053	802	758	1741
Mean	775	945	1540	1710	2010	2100	2470	2650	1960	1120	782	723	1565

Table 260. Modified Mean Discharges, in CFS, Hood River (including PP&L Conduit) near Hood River, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							1947	1695	8083	562	375	362	
1929	525	686	681	716	557	1232	1269	1565	1051	525	354	328	792
1930	400	342	930	545	2202	1051	924	687	473	335	264	284	694
1931	443	520	567	826	748	1602	1951	1029	635	382	273	272	770
1932	439	788	590	1138	927	2452	1602	1483	1004	579	369	345	977
1933	517	1671	1218	1670	910	1265	1467	1530	2149	985	546	602	1210
1934	923	988	4823	3495	1331	1823	1259	668	441	386	317	377	1410
1935	778	1752	1987	1590	1235	1256	1316	1386	1035	620	396	376	1143
1936	438	462	827	540	775	1223	1760	1304	1514	675	333	382	1004
1937	386	368	816	523	758	1261	1817	1647	1575	715	370	392	885
1938	487	1578	2324	2047	1028	1712	1826	1334	805	505	334	344	1196
1939	452	431	1060	1066	1217	1207	1067	838	550	401	261	270	754
1940	386	346	1031	711	1857	1828	1262	853	391	290	233	351	795
1941	432	770	855	943	761	753	541	681	381	264	222	380	582
1942	464	755	1710	686	1182	862	966	919	694	431	266	216	761
1943	344	2280	2568	1829	2193	1620	2705	1668	1325	868	506	383	1517
1944	685	901	926	756	856	817	897	816	601	359	244	300	678
1945	413	524	557	1150	1411	996	1144	1644	678	397	267	366	793
1946	401	998	1866	2021	1309	1620	1317	1610	1175	847	452	1103	1170
1947	756	1480	3214	1522	1651	1311	1186	780	741	523	366	428	1162
1948	1430	1460	1086	2067	1769	1279	1235	1584	1258	630	477	432	1223
1949	678	1285	1946	727	1837	1738	2044	2512	1424	489	562	597	1347
1950	747	1160	1283	674	2015	2515	1922	1462	1921	1106	629	514	1425
1951	1164	1989	2461	2453	2704	1524	1792	1637	984	637	451	439	1512
1952	1313	1136	1608	847	1869	1132	1529	1399	987	660	420	378	1103
1953	359	411	622	3861	2248	1196	1125	1386	1075	722	495	426	1153
1954	491	1117	2510	1730	2053	1650	1900	1540	1398	849	491	439	1343
1955	619	886	991	1015	1098	952	1286	1662	1897	1090	559	522	1047
1956	1166	2710	3198	2162	1178	1833	2148	2173	1561	902	599	551	1684
1957	668	853	1731	726	1145	2106	1988	1566	840	532	406	397	1080
1958	540	782	1981	1848	2360	1128	1797	1301	985	605	443	424	1175
Mean	628	1050	1600	1400	1440	1430	1500	1350	1050	604	397	421	1072

Table 261. Modified Mean Discharges, in CFS, White Salmon nr Underwood, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										878	695	631	
1929	584	595	612	558	508	824	1000	1350	1060	680	581	486	738
1930	450	396	527	446	1460	1020	1280	915	682	538	451	434	712
1931	508	481	455	556	603	953	1692	1356	944	635	531	505	768
1932	524	579	623	822	851	1779	1928	2252	1904	1232	913	722	1177
1933	676	1294	1016	1186	895	1173	1543	1953	2526	1617	1104	1006	1332
1934	992	1051	3858	3842	2318	2233	1727	1223	1011	863	780	730	1719
1935	861	1515	1504	1489	1454	1310	1325	1832	1677	1142	909	676	1308
1936	606	573	562	1322	773	1280	1456	1792	1474	890	711	597	1004
1937	551	496	584	487	549	1032	1627	1612	1641	987	742	654	914
1938	570	1101	1732	1994	1340	1805	1727	1736	1416	962	784	663	1320
1939	634	635	730	825	964	1049	1112	1118	803	644	518	490	793
1940	475	431	760	680	1557	1892	1695	1291	823	651	537	520	940
1941	500	559	771	879	941	964	986	910	666	533	469	513	723
1942	505	647	1502	889	1317	960	1147	1067	901	634	538	458	878
1943	443	961	1384	1318	1446	1544	2518	1845	1703	1178	825	717	1321
1944	679	623	728	657	810	742	822	804	642	514	457	437	659
1945	437	496	452	724	1130	1040	1134	1608	1001	730	598	560	824
1946	498	612	1137	1623	1318	1480	1376	1814	1572	1079	761	704	1164
1947	682	954	2194	1335	1774	1459	1377	1049	899	650	585	604	1127
1948	975	1036	949	1679	1543	1355	1267	1841	1631	910	752	669	1216
1949	630	793	1117	682	1406	1974	1878	2354	1761	1140	821	739	1273
1950	699	968	1021	991	1464	2399	2096	1994	2155	1420	1005	812	1417
1951	1003	1583	2504	2203	2675	1813	2018	2085	1537	1055	844	761	1667
1952	991	1001	1495	997	1813	1269	1558	1656	1307	969	757	642	1201
1953	556	566	581	2542	2132	1413	1317	1608	1400	1046	770	649	1211
1954	666	811	1463	1442	1838	1808	1833	1797	1680	1210	880	774	1347
1955	751	911	813	899	960	925	1149	1257	1608	1076	778	734	987
1956	900	1607	2349	2010	1313	1812	2269	2565	2506	1640	1136	936	1755
1957	851	835	1252	812	1056	1915	1793	1748	1090	807	677	594	1120
1958	619	641	1112	1521	2433	1494	1804	1728	1279	852	692	629	1226
Mean	661	821	1193	1237	1355	1424	1548	2209	1345	943	730	647	1176

Table 262. Modified Mean Discharges, in CFS, Columbia River at Bonneville Dam, Oregon-Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										254855	128045	113714	
1929	115040	121865	136055	144900	158875	146665	140430	131975	136051	116740	117820	118345	132065
1930	117140	123755	142350	142805	164010	139095	132655	134675	130785	116110	117710	115155	131353
1931	118895	121690	139995	140670	142470	145047	153535	138985	135565	120010	117130	107100	131757
1932	115995	122910	139145	155365	150365	178910	183220	276080	255255	121650	122195	123845	162077
1933	125080	122865	146415	187555	228210	172775	191710	282050	352455	226030	154505	137685	193944
1934	143060	164420	235755	243980	292536	283600	326888	295635	210145	133550	124135	124515	214852
1935	114885	122310	158395	184495	198630	167375	176615	227865	236065	165915	127920	122165	166886
1936	122095	125175	142220	180125	143775	158345	166715	277480	202525	119180	121480	120446	156630
1937	120010	125360	139985	145135	152110	145645	142900	144440	138210	120950	123680	120940	134947
1938	118665	119440	147320	183375	204600	191650	219730	253755	263440	212820	124445	119990	179945
1939	122185	122510	134010	172695	144025	162660	181940	190495	161760	124580	123610	121535	146833
1940	118090	125475	131270	180420	175365	186800	188890	184420	154710	123605	125655	122410	151425
1941	119675	128670	142285	155055	156660	155055	185500	151075	155670	125480	122750	121820	143308
1942	128250	129155	165365	173650	206005	159595	199715	202850	234855	144225	127390	123470	166210
1943	121420	119890	152270	186725	261200	236080	288455	363445	251330	216915	132790	120840	204279
1944	117855	123435	136515	140345	163160	137140	144505	143020	145085	121900	118455	110210	134301
1945	117930	124655	137575	147620	153970	142950	143270	198310	150800	124825	124570	120205	140556
1946	121900	121960	139535	168685	196390	201935	217525	280570	260810	181807	124065	126095	178439
1947	123845	138575	186410	179845	231465	231915	227885	302535	254100	179945	120680	116650	191153
1948	138025	158255	173235	187305	293045	264260	238385	337170	459820	258200	154025	136520	233186
1949	128855	132685	143855	177235	210570	205065	221130	309050	281320	119720	119700	118065	180603
1950	116475	117150	153965	179215	257455	276530	255010	305685	339590	290225	145085	130805	213932
1951	140530	159545	177885	192975	356500	307730	321475	301625	268600	224810	145240	125050	226830
1952	141420	151520	169060	182030	249545	215930	252470	341965	262470	200050	119070	118275	200316
1953	119430	123400	140285	185570	226145	170690	181115	275205	300185	197960	128865	122130	180914
1954	122860	136170	166895	184055	249580	233885	204370	290160	317860	288410	196875	149800	211742
1955	138160	151645	166285	181765	202330	150735	165400	191855	289750	250025	138040	122380	179030
1956	139140	159415	192385	200545	294630	345815	308215	413280	391495	257045	138260	127940	247346
1957	130965	134540	168815	184075	228370	223720	226495	326485	328443	164195	117645	119060	196067
1958	118945	120825	134700	181950	239525	203100	242015	303475	289880	225000	134000	107200	191717
Mean	124560	131642	154675	175005	211050	195023	207605	252523	245300	175730	130260	122335	177400

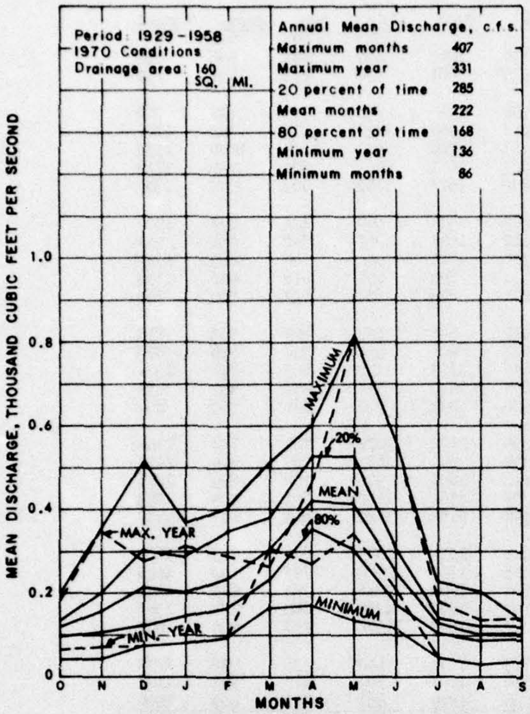


Figure 429 Monthly discharge, Walla Walla River near Milton, Oregon

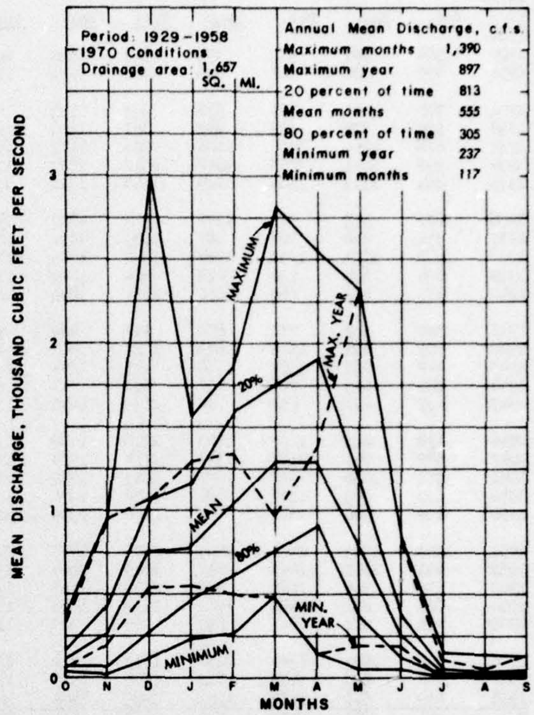


Figure 430 Monthly discharge, Walla Walla River near Touchet, Washington

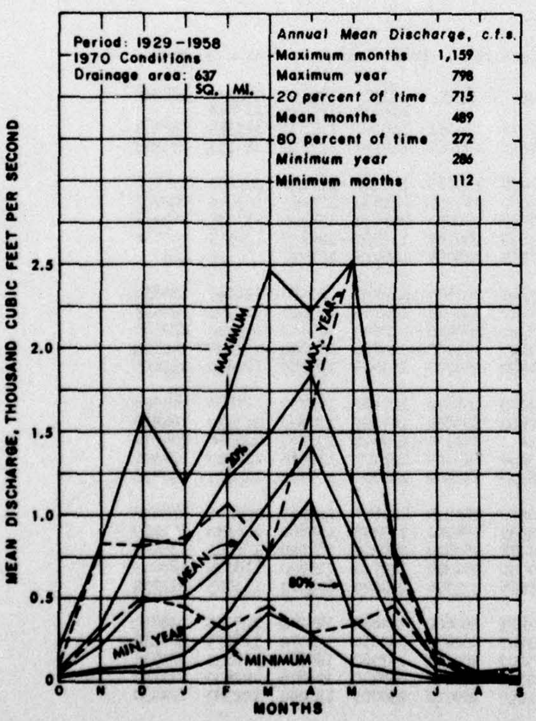


Figure 431 Monthly discharge, Umatilla River at Pendleton, Oregon

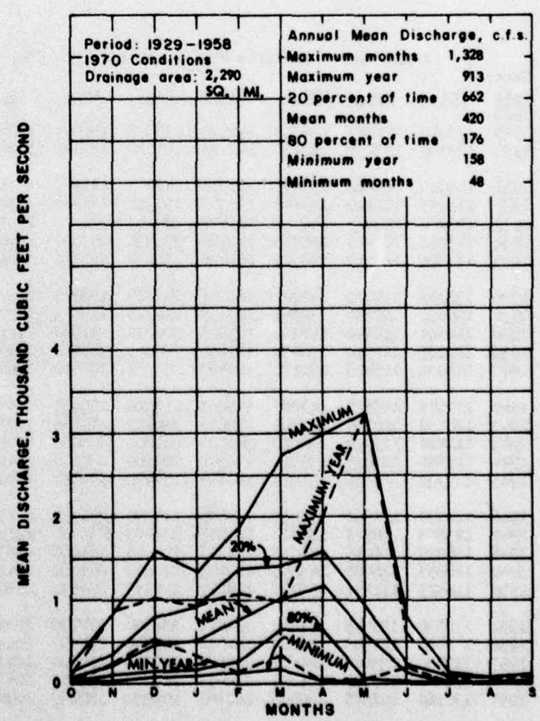


Figure 432 Monthly discharge, Umatilla River near Umatilla, Oregon

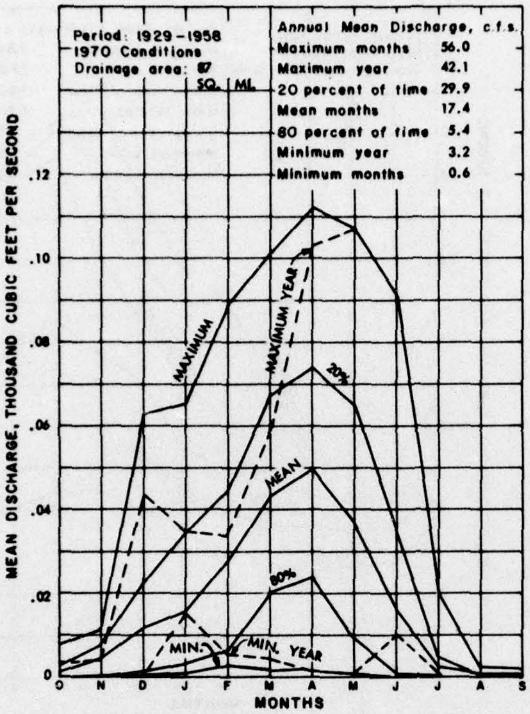


Figure 433 Monthly discharge, Willow Creek at Heppner, Oregon

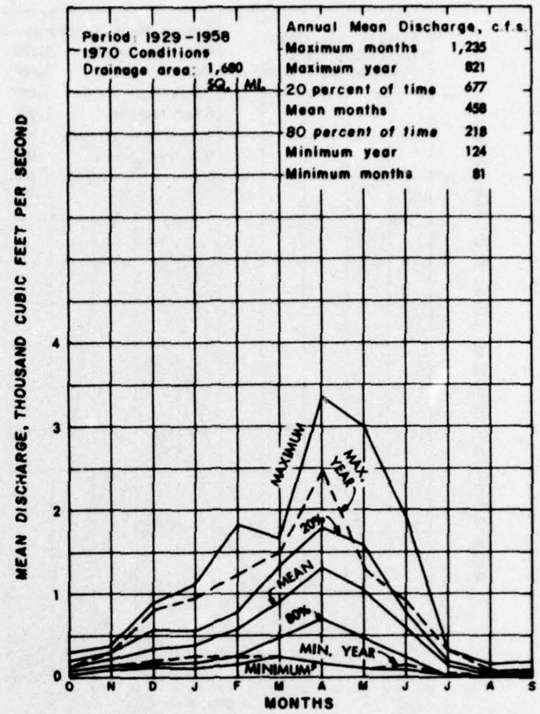


Figure 434 Monthly discharge, John Day River at Picture Gorge, near Dayville, Oregon

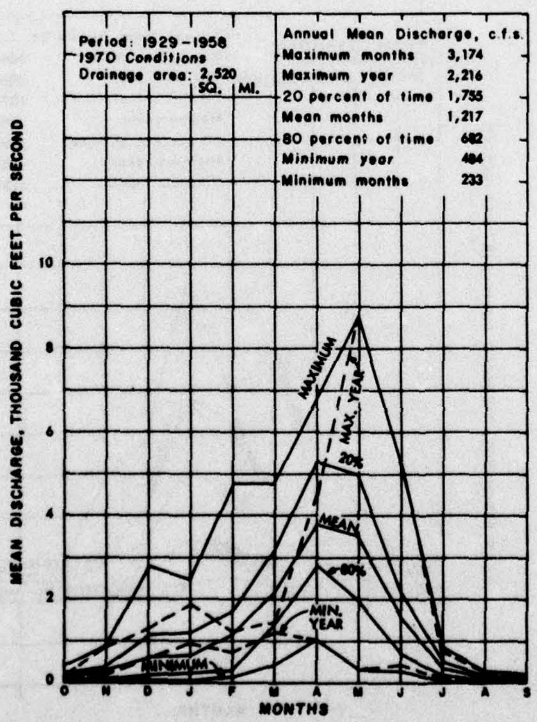


Figure 435 Monthly discharge, North Fork John Day River at Monument, Oregon

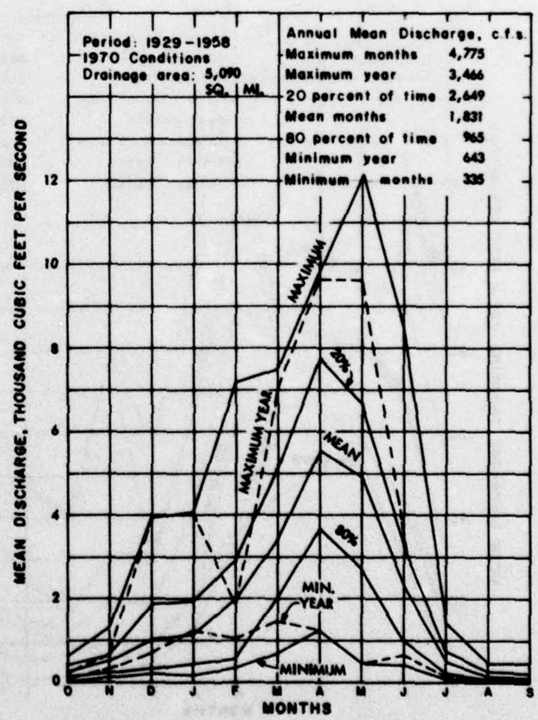


Figure 436 Monthly discharge, John Day River at Service Creek, Oregon

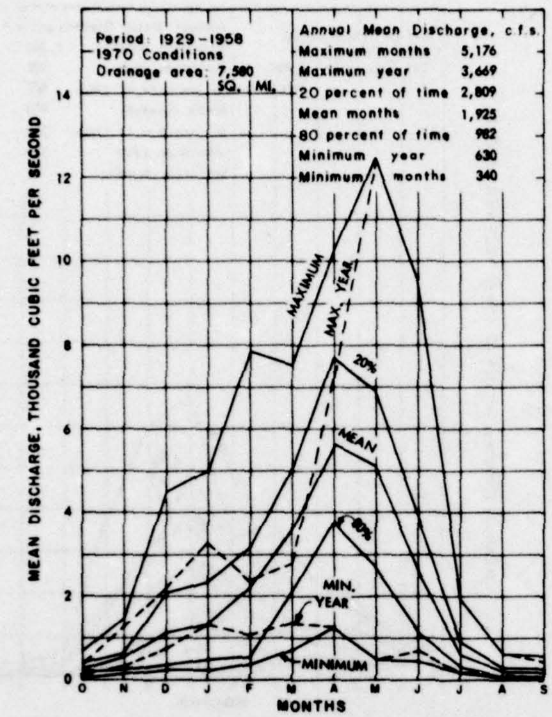


Figure 437 Monthly discharge, John Day River at McDonald Ferry, Oregon

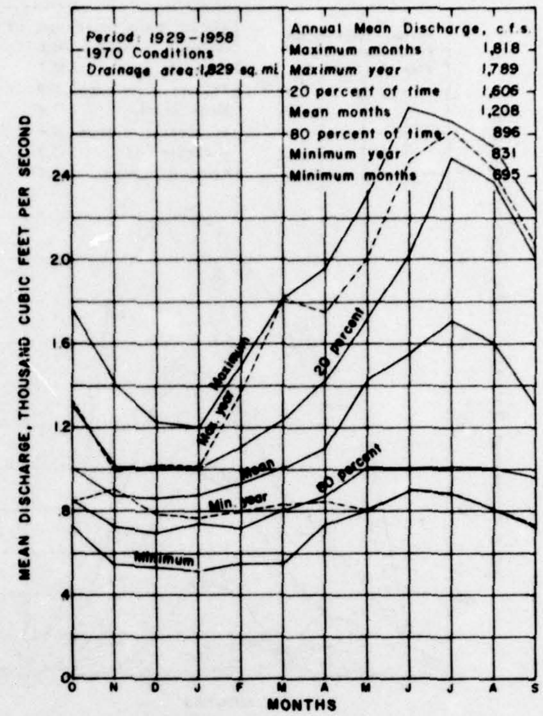


Figure 438 Monthly discharge, Deschutes River below Lava Island near Bend, Oregon

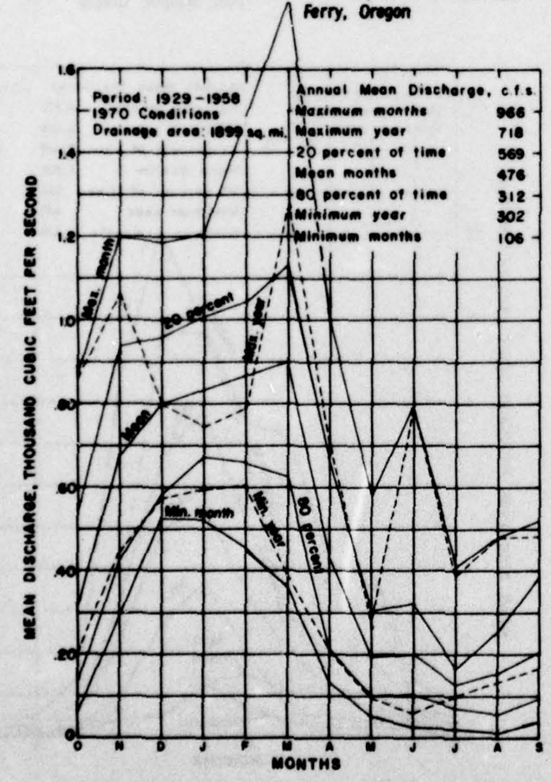


Figure 439 Monthly discharge, Deschutes River below Bend, Oregon

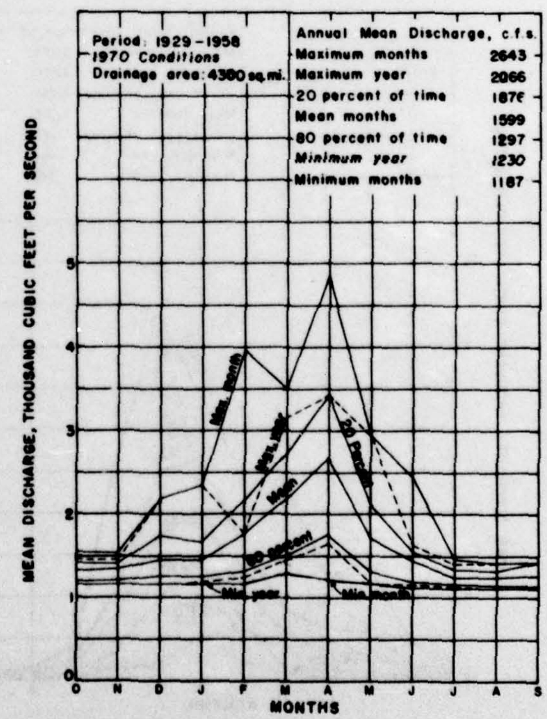


Figure 440 Monthly discharge, Crooked River near Culver, Oregon

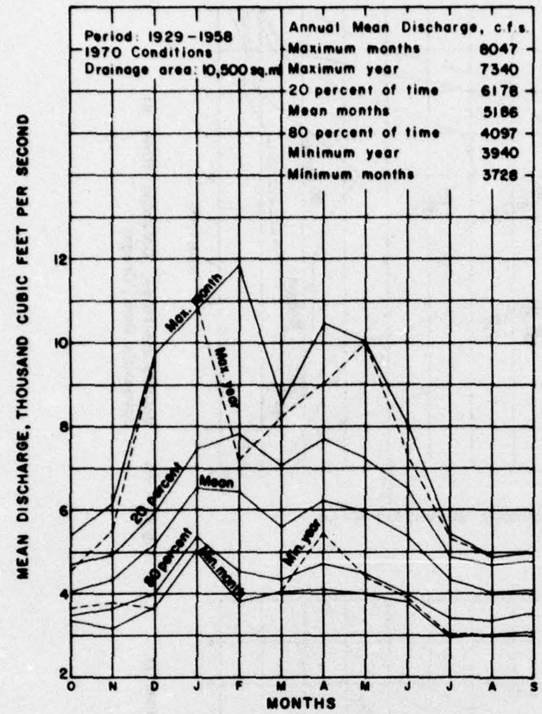


Figure 441 Monthly discharge, Deschutes River at Moody near Biggs, Oregon

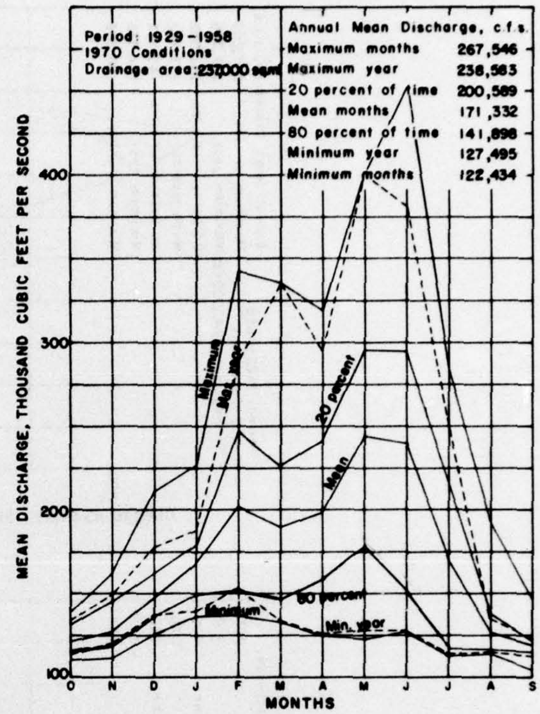


Figure 442 Monthly discharge, Columbia River at The Dalles, Oregon

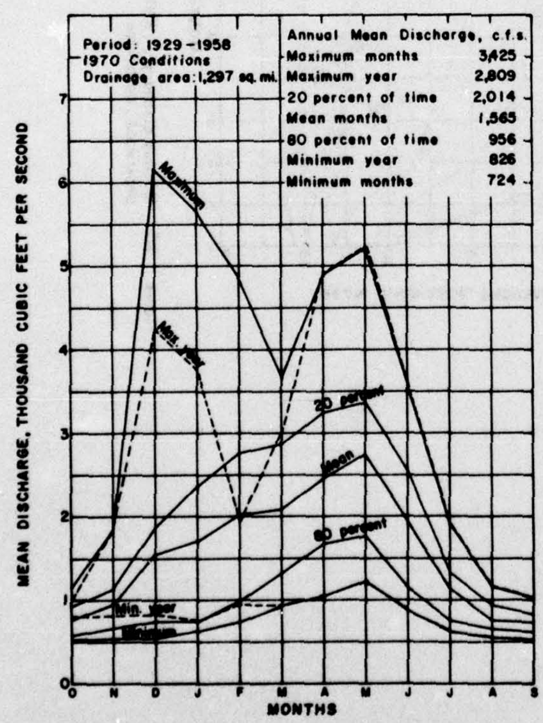


Figure 443 Monthly discharge, Klickitat River nr. Pitt, Washington

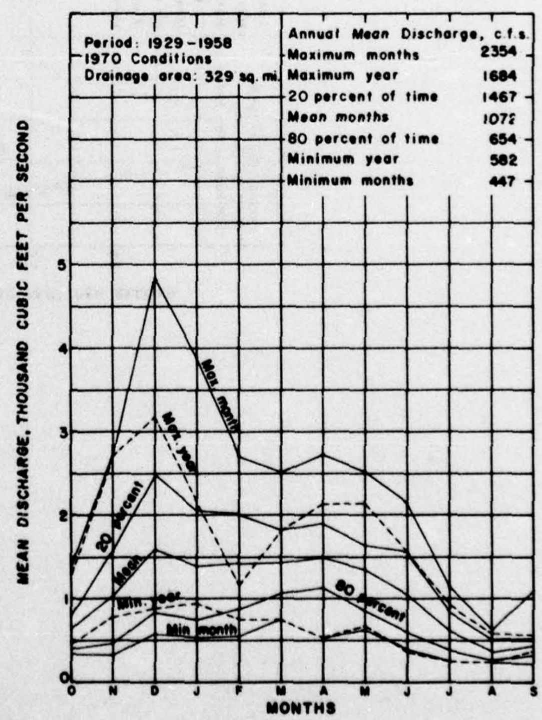


Figure 444 Monthly discharge, Hood River (Including P.P.&L. Conduit) nr Hood River, Oregon

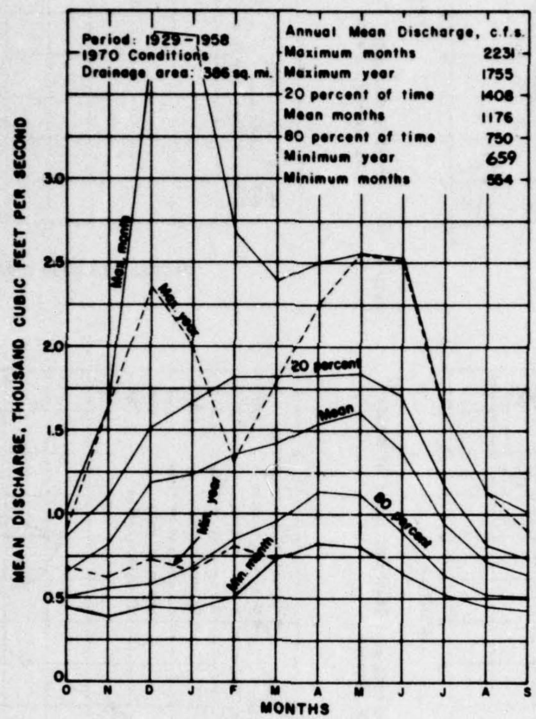


Figure 445 Monthly discharge, White Salmon River nr. Underwood, Washington

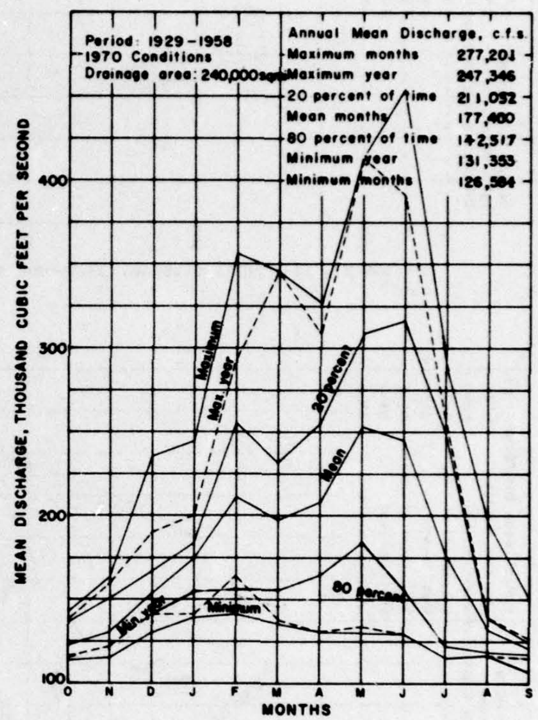


Figure 446 Monthly discharge, Columbia River at Bonneville Dam, Oregon

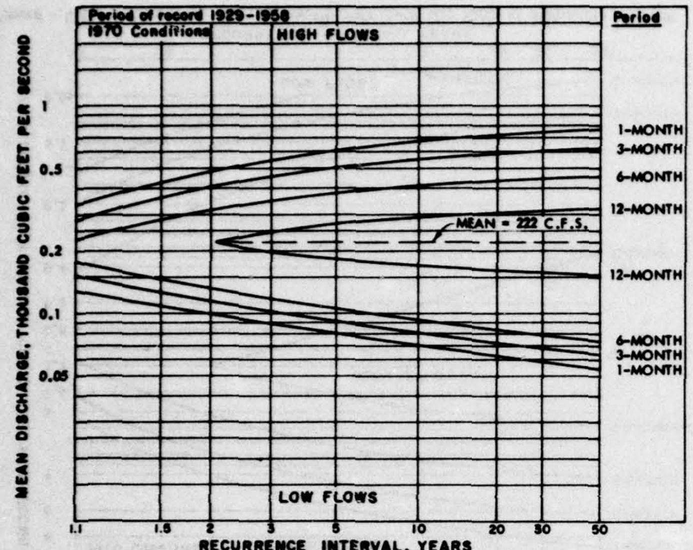


Figure 447 Frequency curves, Walla Walla River near Milton, Oregon

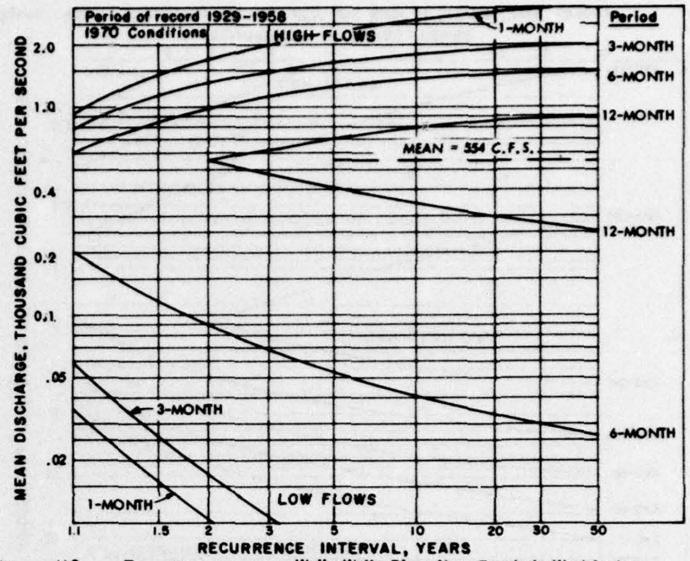


Figure 448 Frequency curves, Walla Walla River Near Touchet, Washington

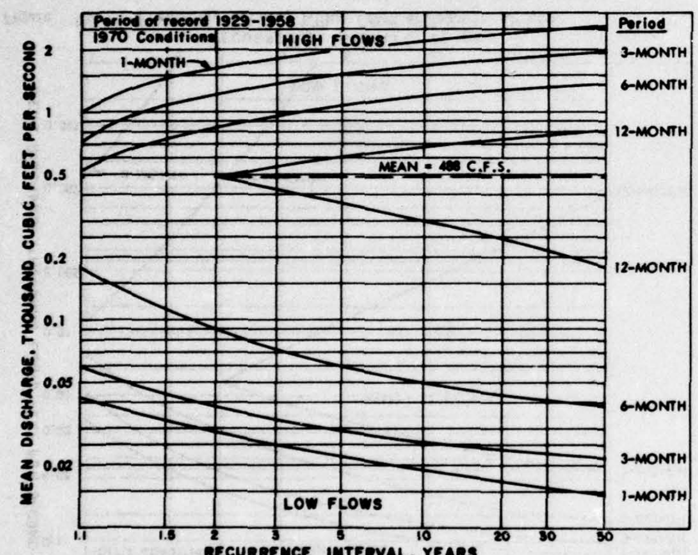


Figure 449 Frequency curves, Umatilla River at Pendleton, Oregon

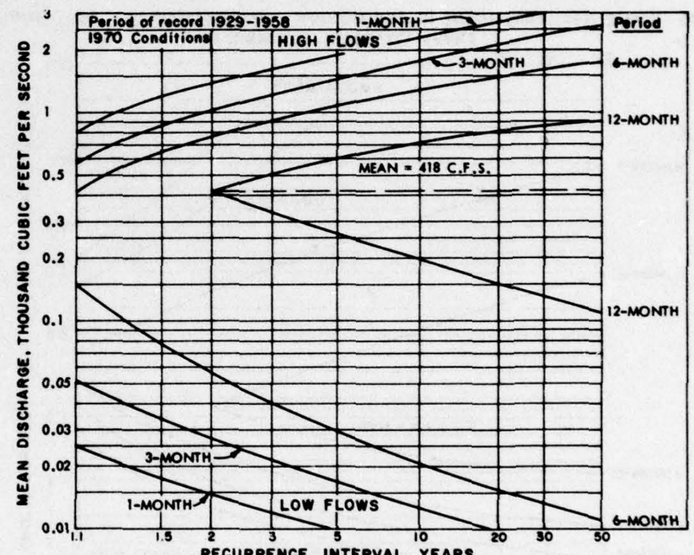


Figure 450 Frequency curves, Umatilla River near Umatilla, Oregon

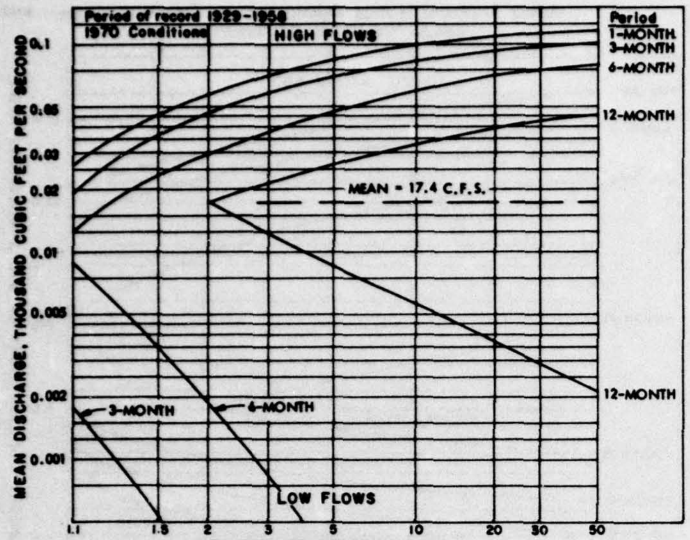


Figure 451 Frequency curves, Willow Creek at Heppner, Oregon

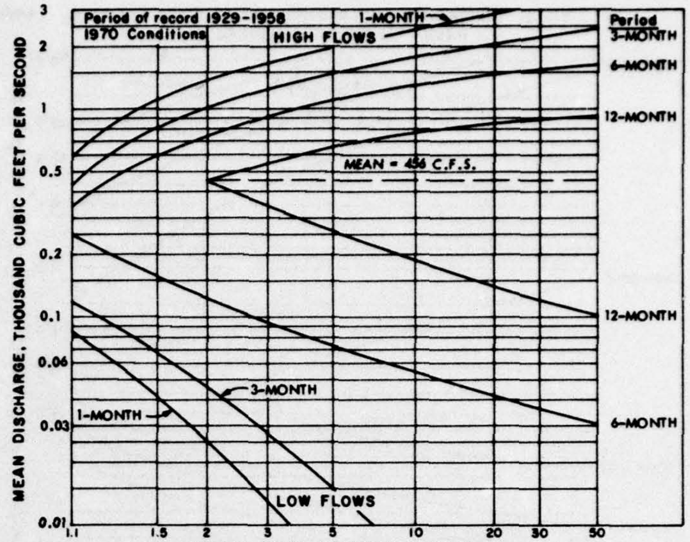


Figure 452 Frequency curves, John Day River at Picture Gorge, near Dayville, Oregon

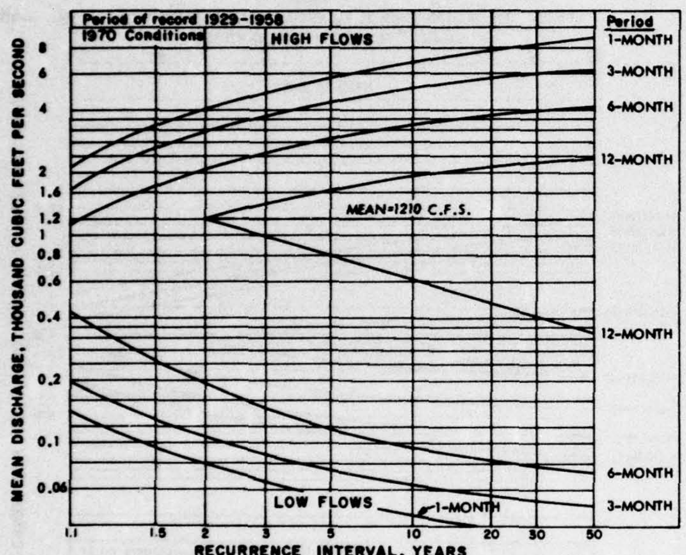


Figure 453 Frequency curves, North Fork John Day River at Monument, Oregon

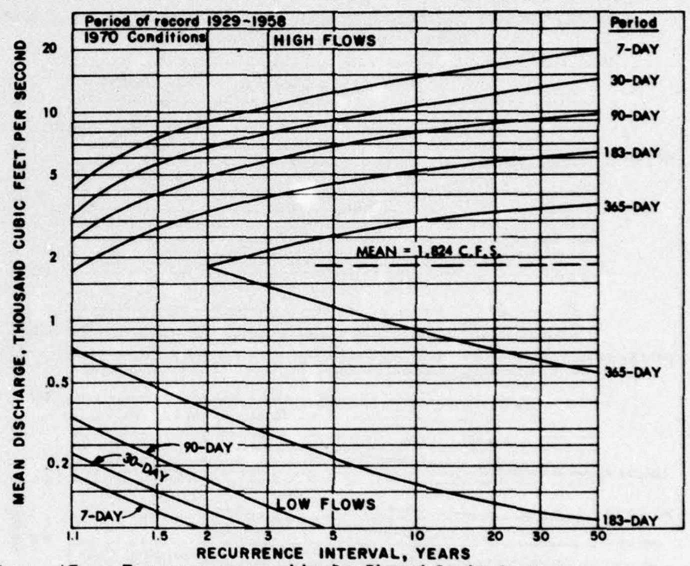


Figure 454 Frequency curves, John Day River at Service Creek, Oregon

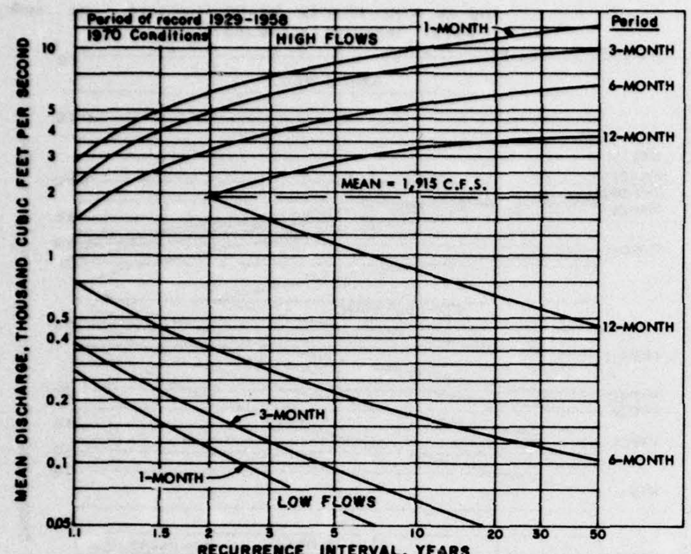


Figure 455 Frequency curves, John Day River at McDonald Ferry, Oregon

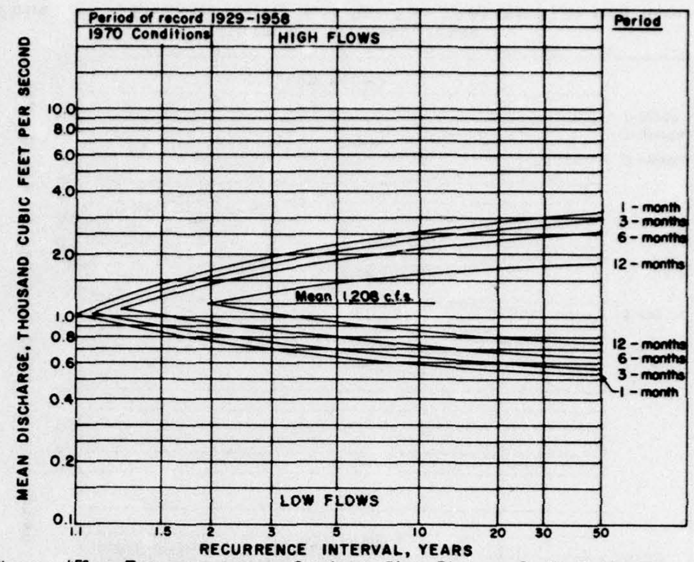


Figure 456 Frequency curves, Deschutes River Bl. Lava Is. Nr. Bend

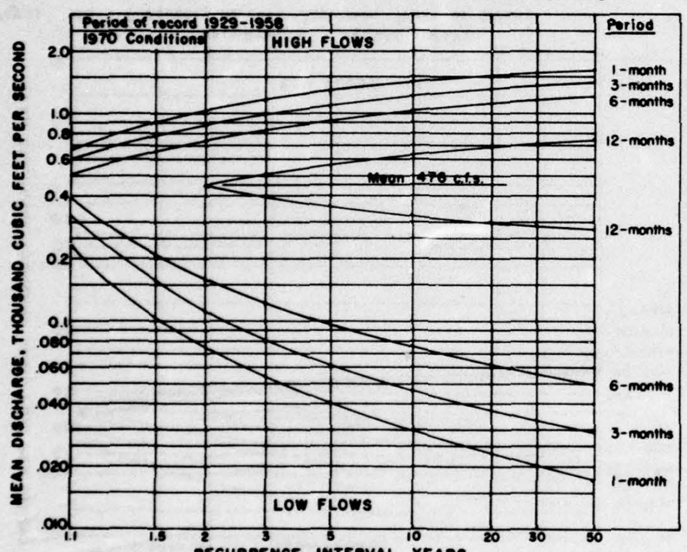


Figure 457 Frequency curves, Deschutes River Bl. Bend

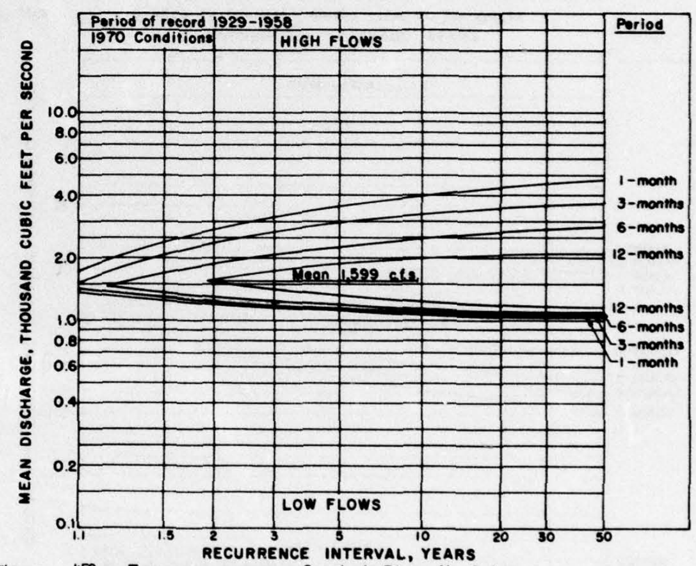


Figure 458 Frequency curves, Crooked River Nr. Culver

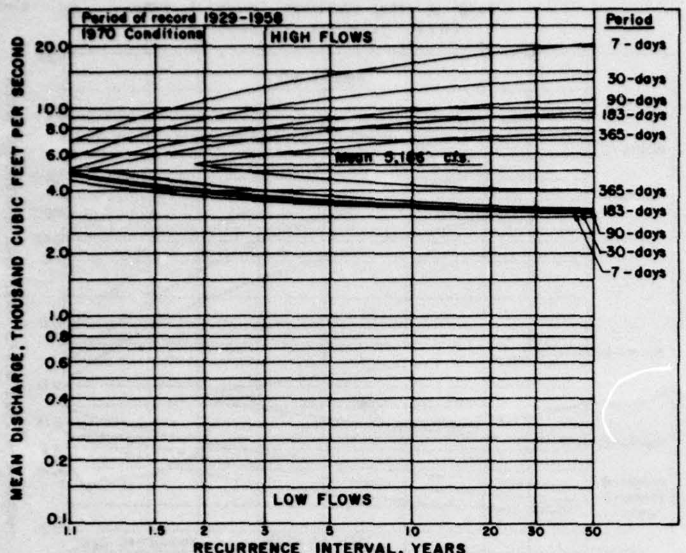


Figure 459 Frequency curves, Deschutes River at Moody

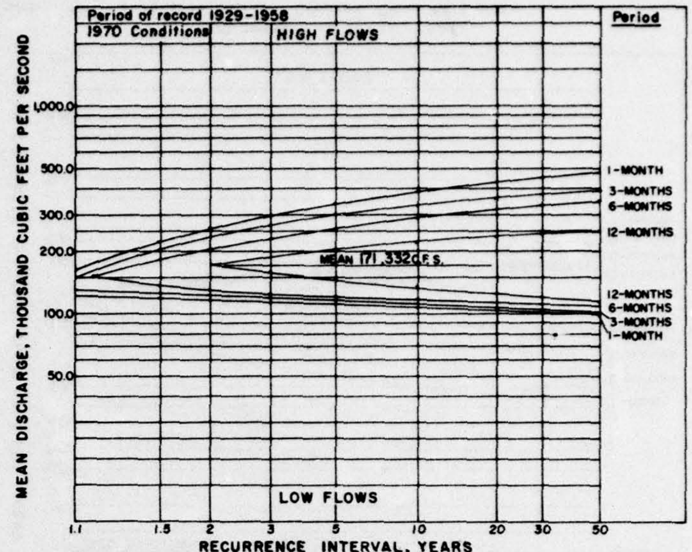


Figure 460 Frequency curves, Columbia River at The Dalles

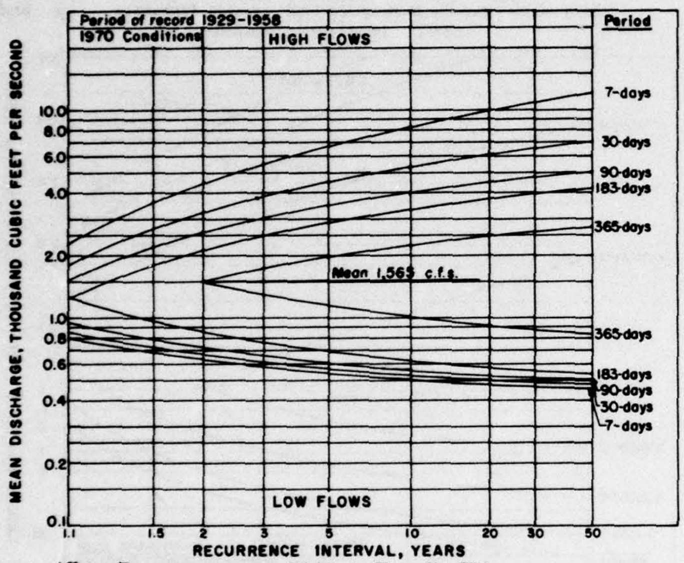


Figure 461 Frequency curves, Klickitat River Nr. Pitt

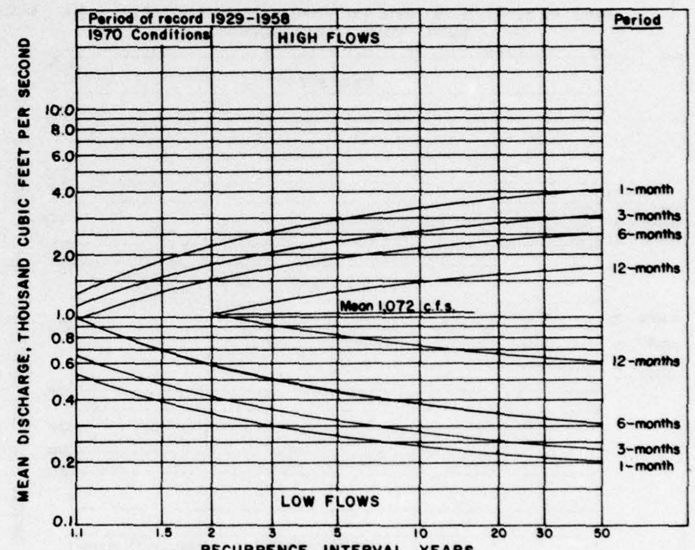


Figure 462 Frequency curves, Hood River (Inc. PP&L Conduit) Nr. Hood River

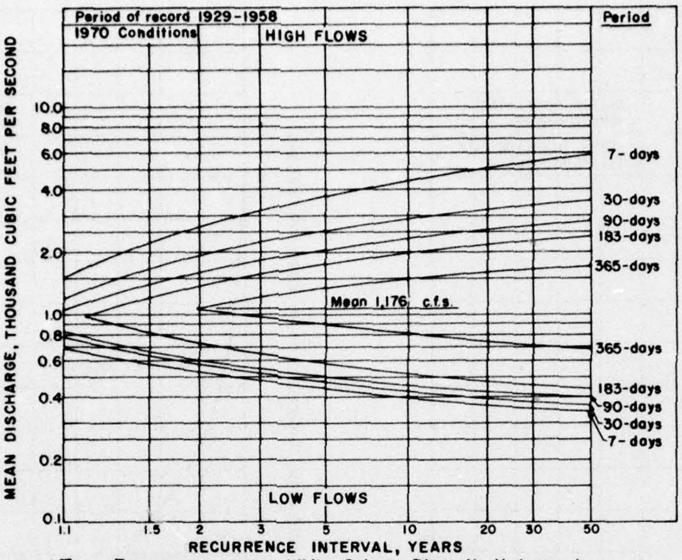


Figure 463 Frequency curves, White Salmon River Nr. Underwood

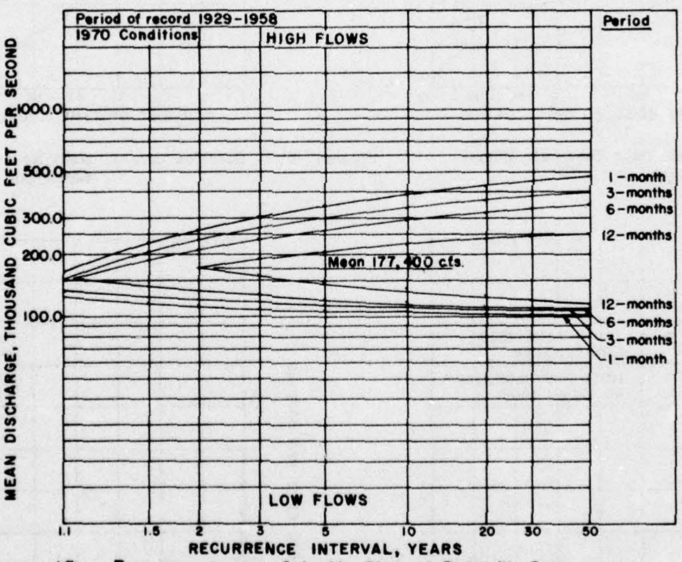


Figure 464 Frequency curves, Columbia River at Bonneville Dam

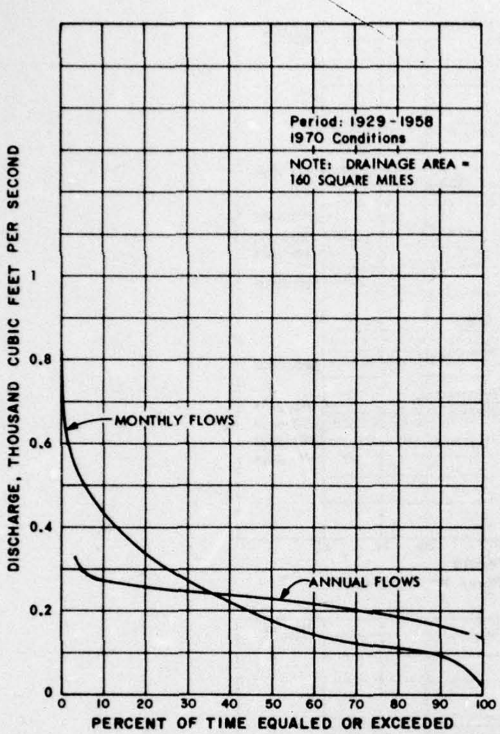


Figure 465 Duration curves, Walla Walla River near Milton, Oregon

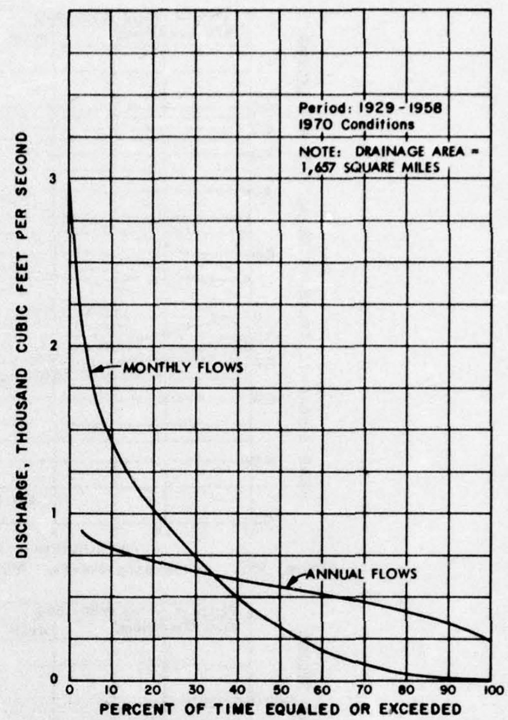


Figure 466 Duration curves, Walla Walla River near Touchet, Washington

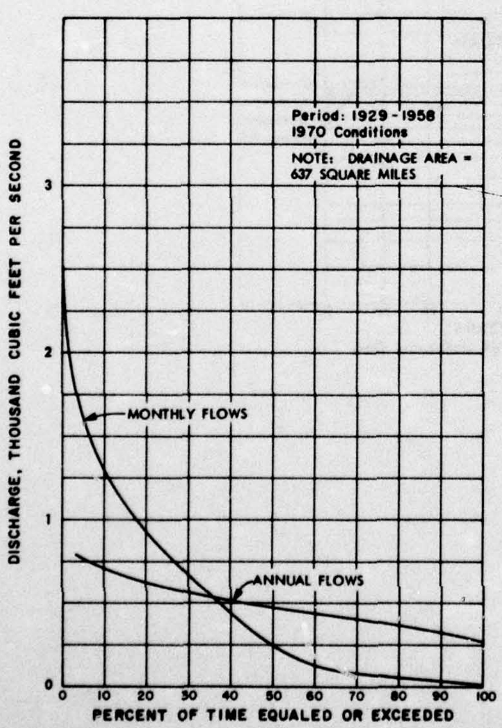


Figure 467 Duration curves, Umatilla River at Pendleton, Oregon

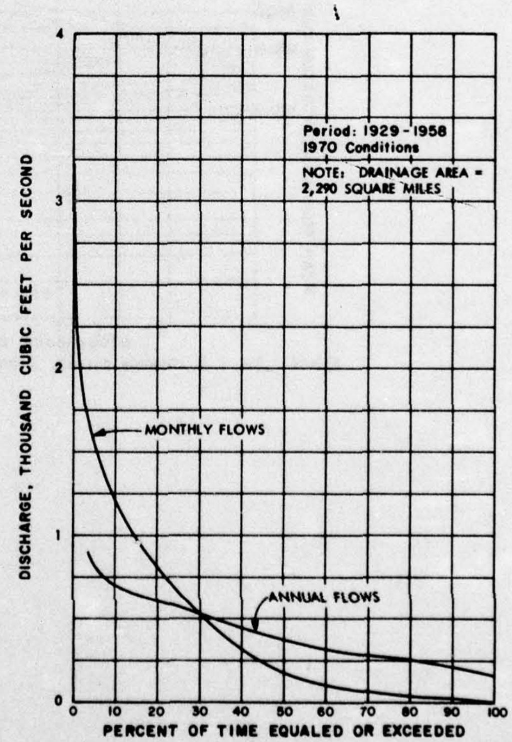


Figure 468 Duration curves, Umatilla River near Umatilla, Oregon

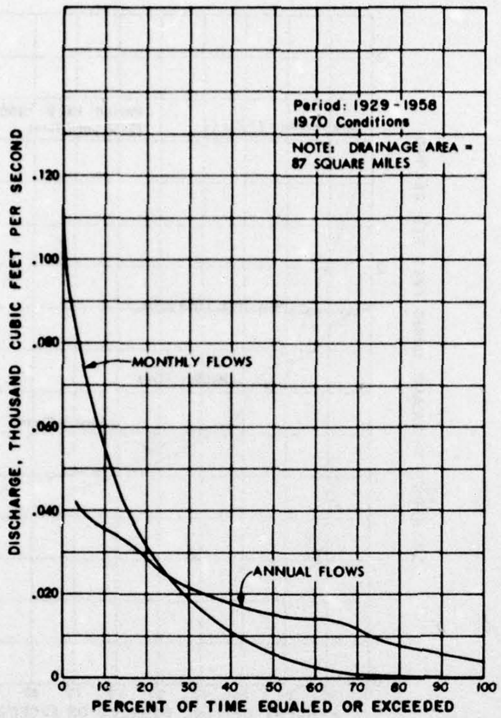


Figure 469 Duration curves, Willow Creek at Heppner, Oregon

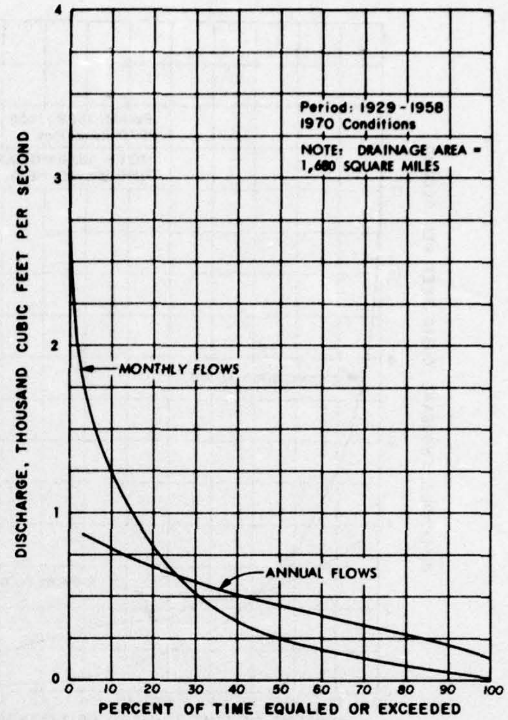


Figure 470 Duration curves, John Day River at Picture Gorge, near Dayville, Oregon

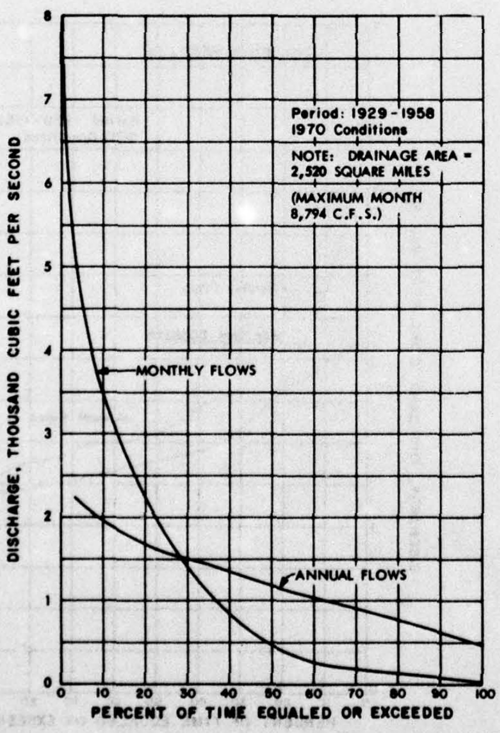


Figure 471 Duration curves, North Fork John Day River at Monument, Oregon

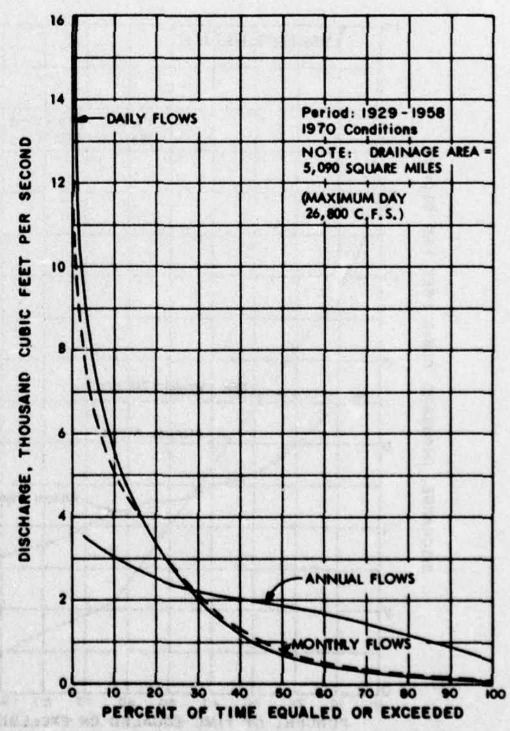


Figure 472 Duration curves, John Day River at Service Creek, Oregon

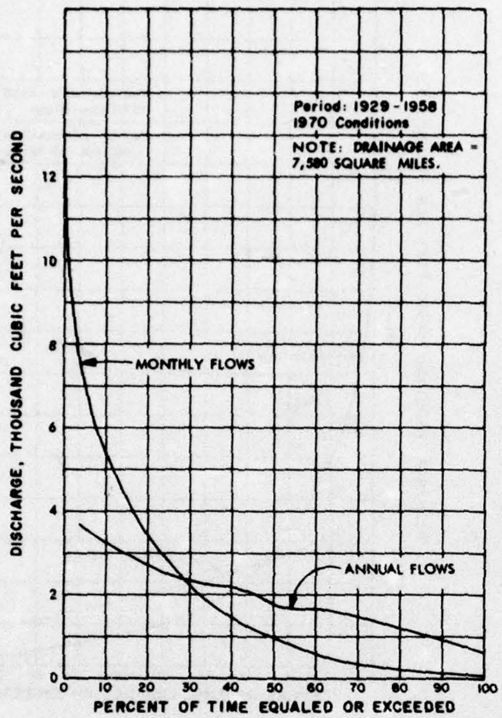


Figure 473 Duration curves, John Day River at McDonald Ferry, Oregon

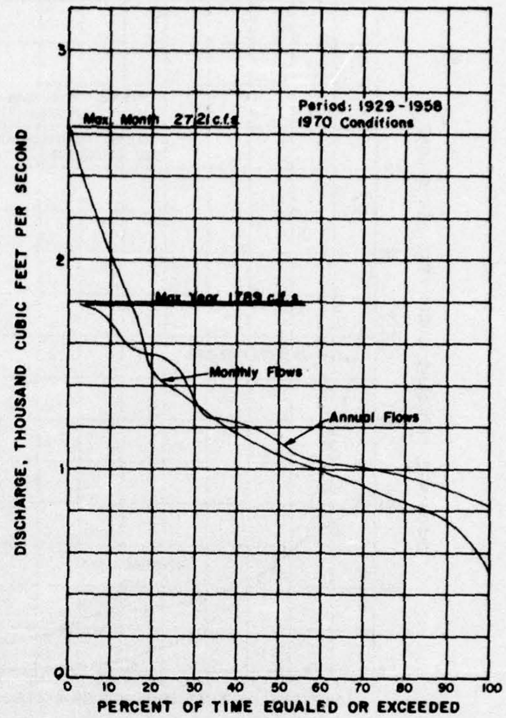


Figure 474 Duration curves, Deschutes River below Lava Island near Bend, Oregon

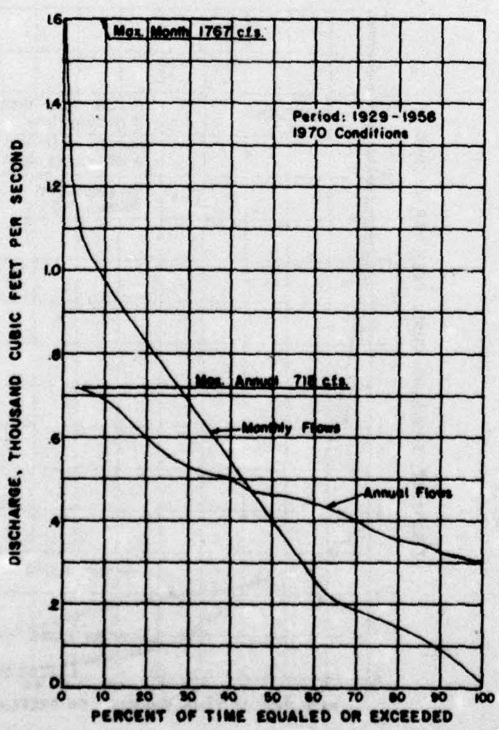


Figure 475 Duration curves, Deschutes River below Bend, Oregon

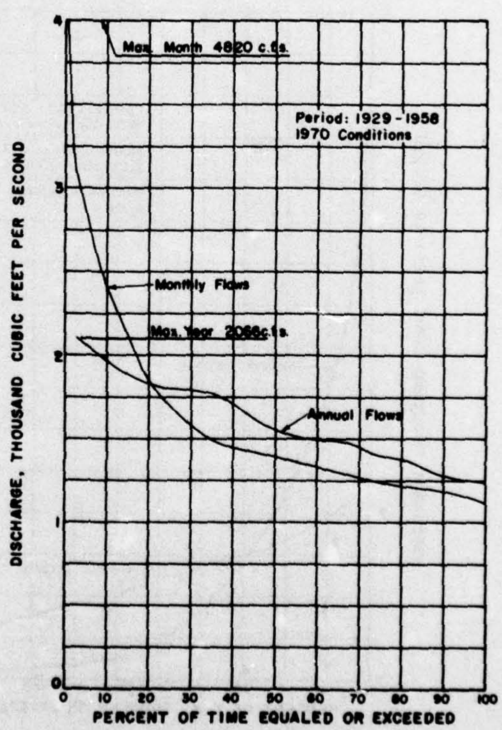


Figure 476 Duration curves, Crooked River near Culver, Oregon

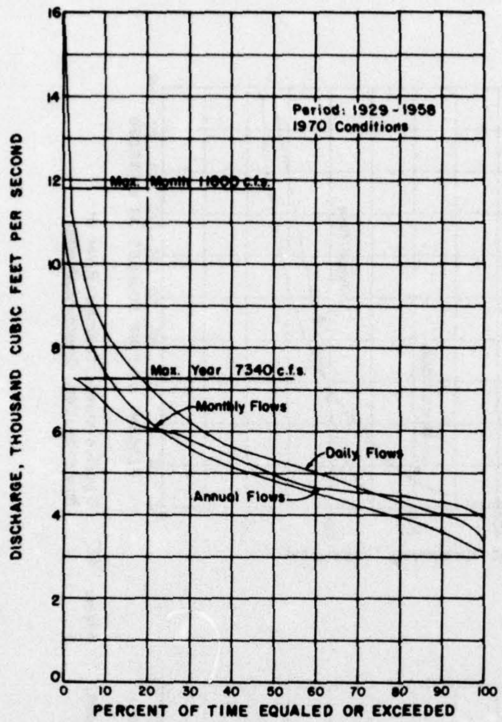


Figure 477 Duration curves, Deschutes River at Moody, Oregon

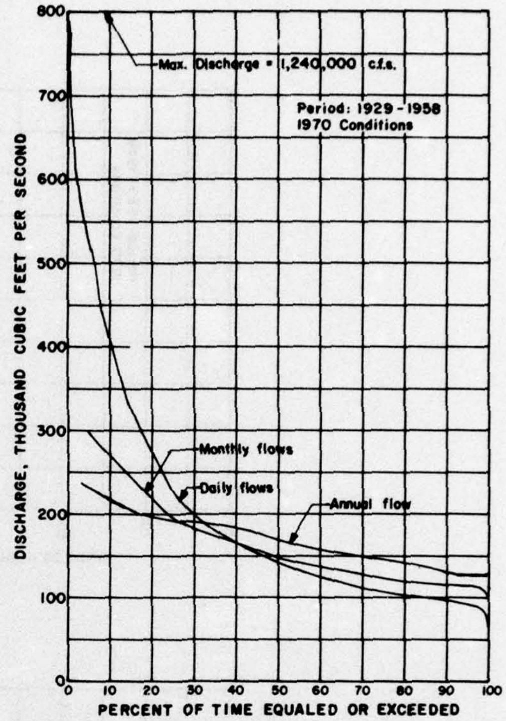


Figure 478 Duration curves, Columbia River at The Dalles, Oregon - Washington

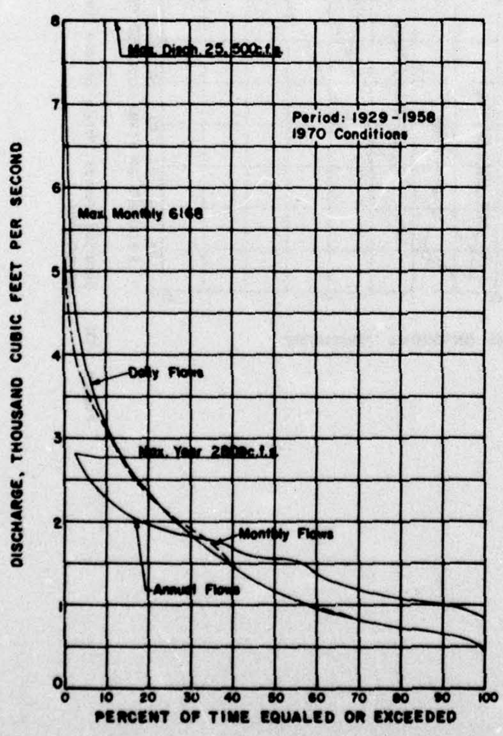


Figure 479 Duration curves, Klickitat River near Pitt, Washington

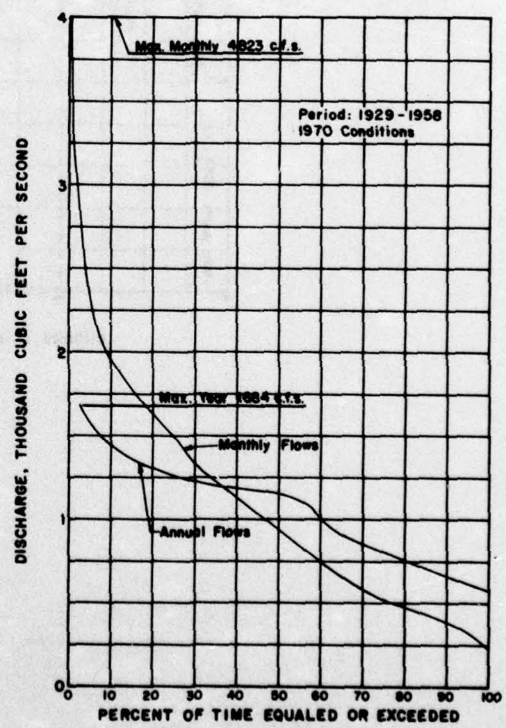


Figure 480 Duration curves, Hood River (Inc. P.P.& L. Conduit) nr. Hood River, Oregon

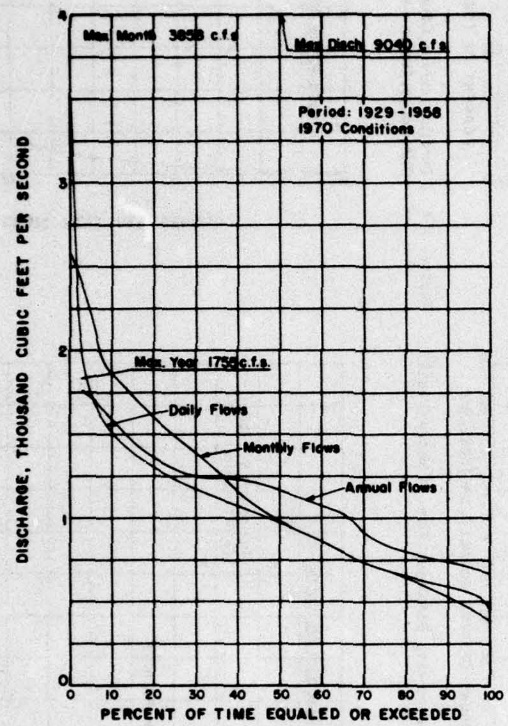


Figure 481 Duration curves, White Salmon River nr Underwood, Washington

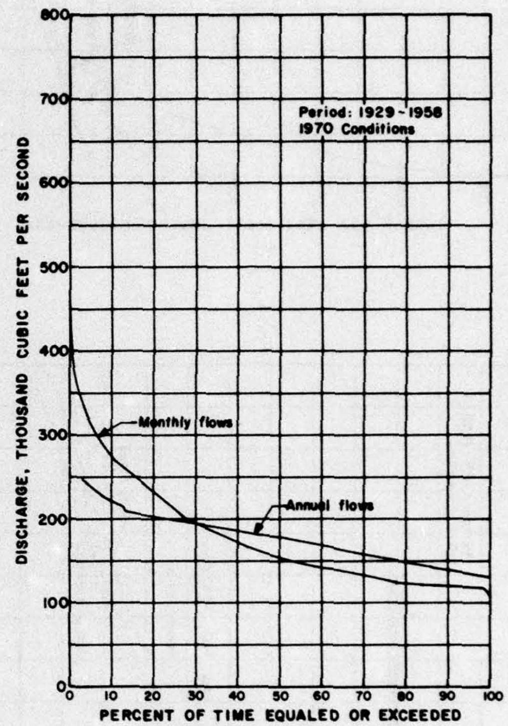


Figure 482 Duration curves, Columbia River at Bonneville Dam, Oregon-Washington

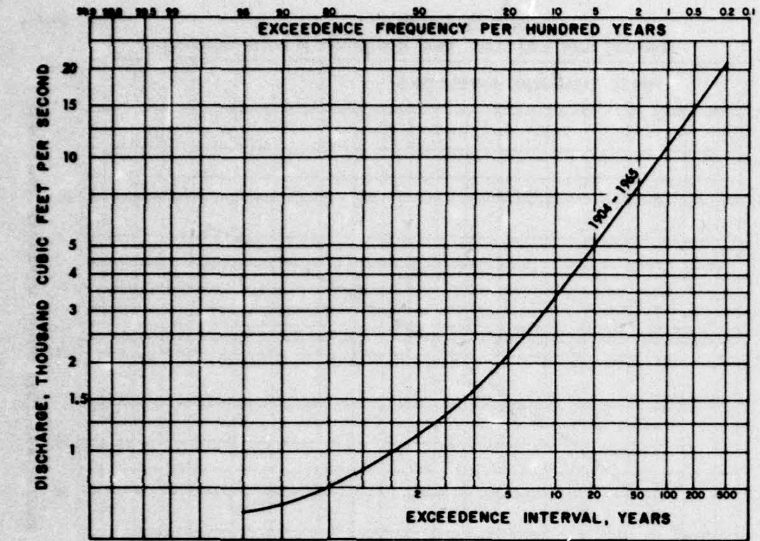


Figure 483 Frequency curve of annual peak flows, Walla Walla River near Milton, Oregon

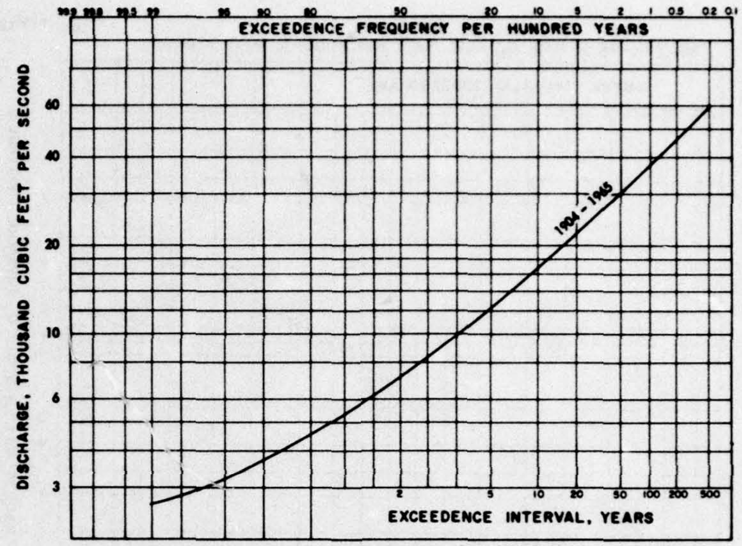


Figure 484 Frequency curve of annual peak flows, Walla Walla River near Touchet, Washington

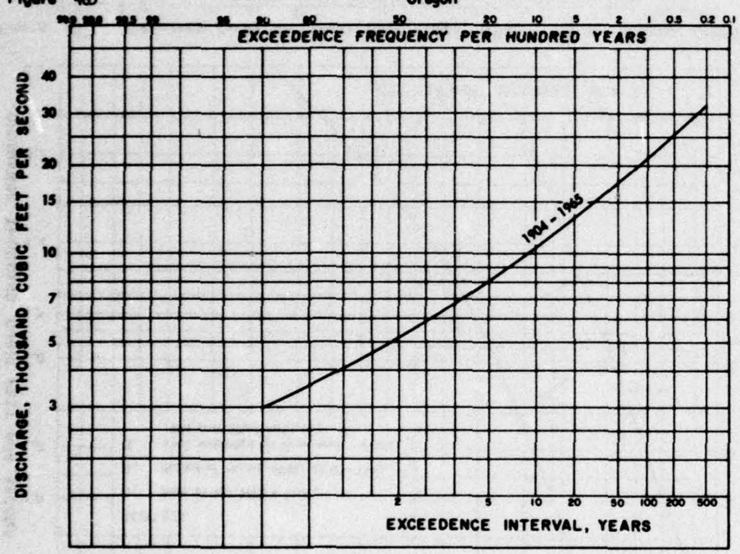


Figure 485 Frequency curve of annual peak flows, Umatilla River at Pendleton, Oregon

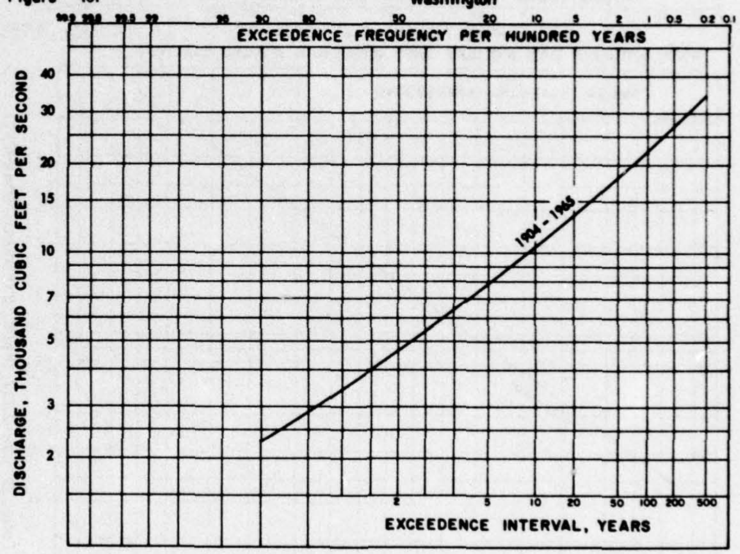


Figure 486 Frequency curve of annual peak flows, Umatilla River nr. Umatilla, Oregon

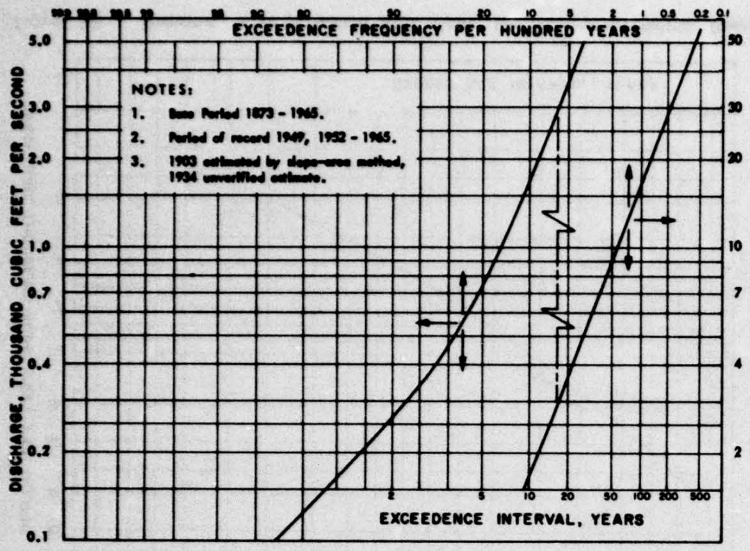


Figure 487 Frequency curve of annual peak flows, Willow Creek at Heppner, Oregon

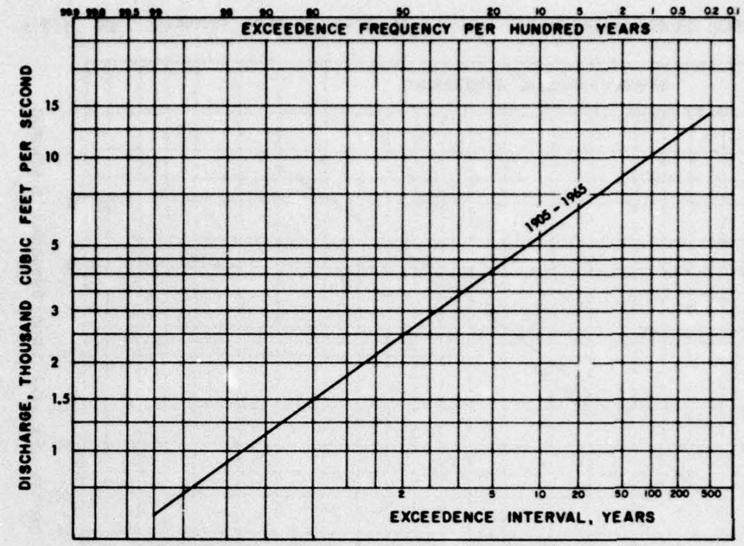


Figure 488 Frequency curve of annual peak flows, John Day River at Picture Gorge, near Dayville, Oregon

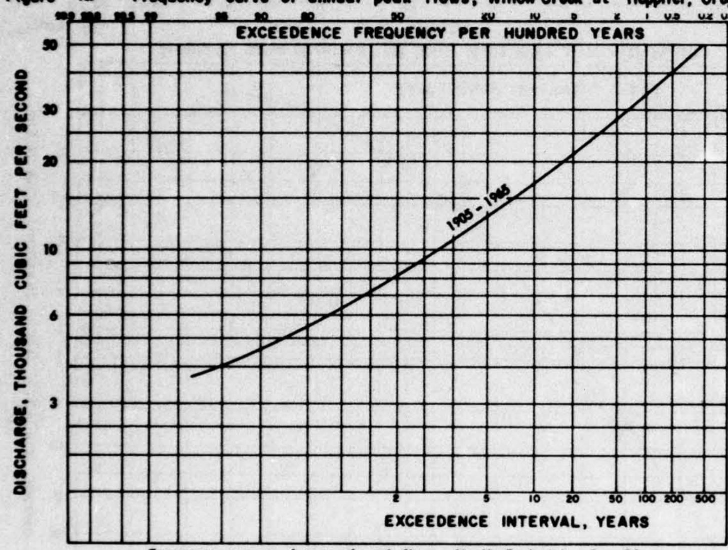


Figure 489 Frequency curve of annual peak flows, North Fork John Day River at Monument, Oregon

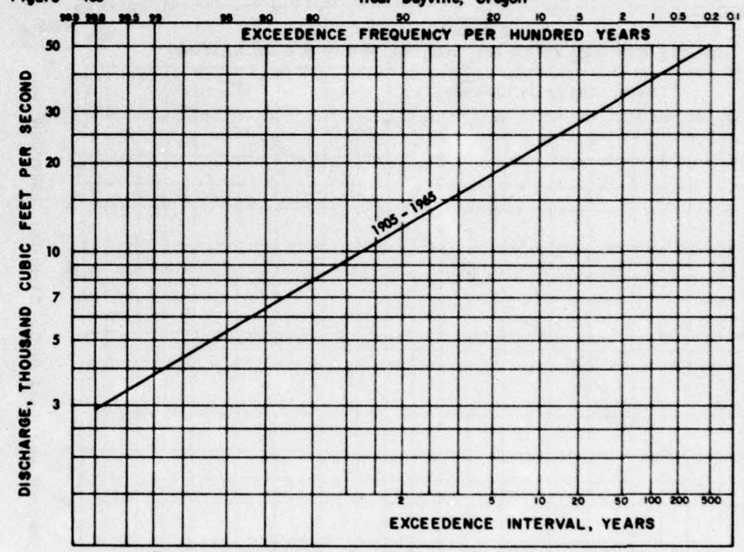


Figure 490 Frequency curve of annual peak flows, John Day River at Service Creek, Oregon

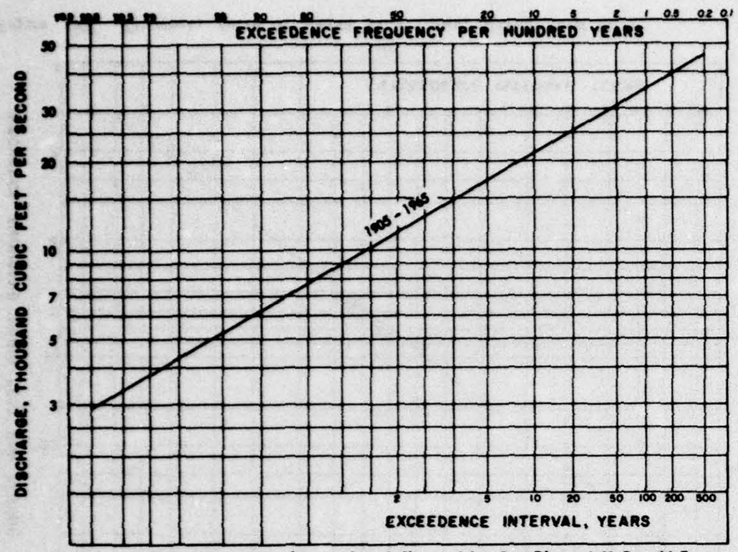


Figure 491 Frequency curve of annual peak flows, John Day River at McDonald Ferry, Oregon

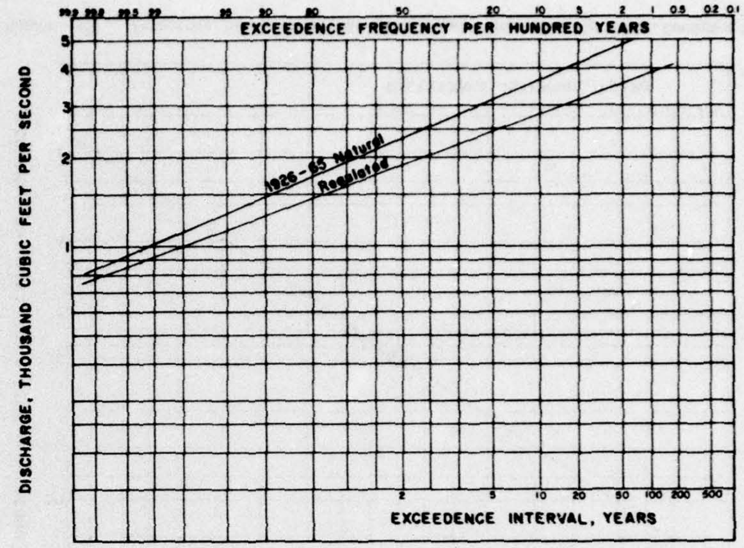


Figure 492 Frequency curve of annual peak flows, Deschutes River bl. Lava Is. nr Bend

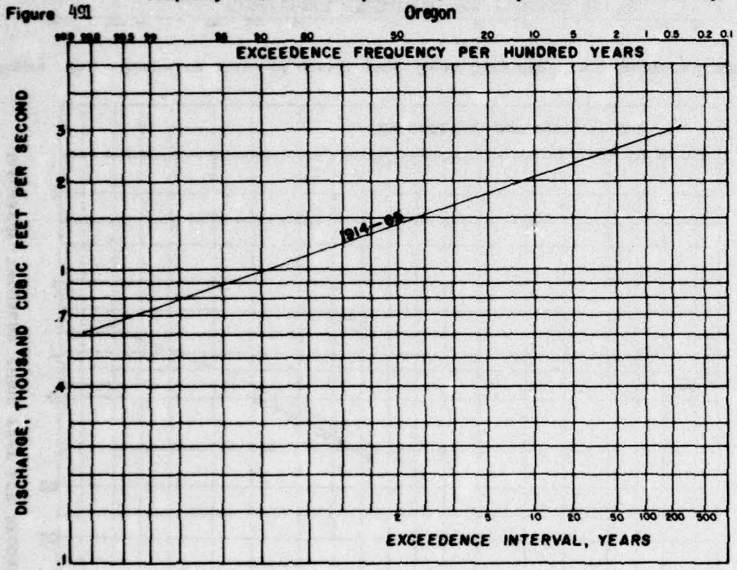


Figure 493 Frequency curve of annual peak flows, Deschutes River below Bend

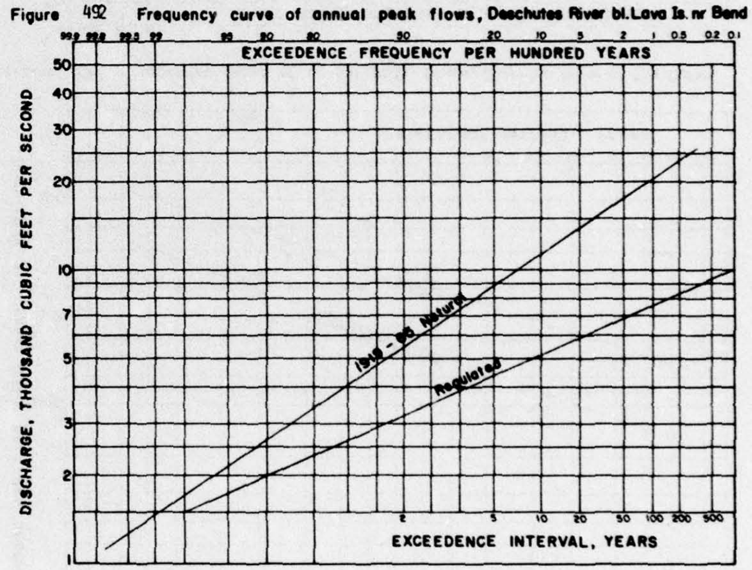


Figure 494 Frequency curve of annual peak flows, Crooked River nr Culver

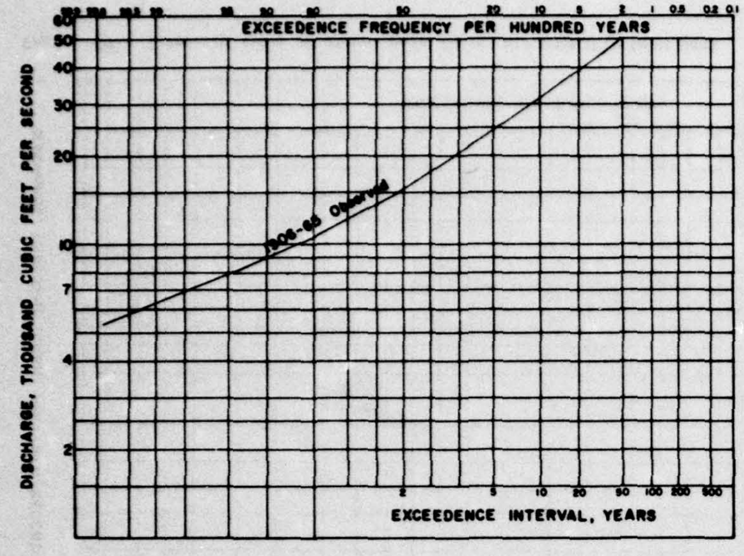


Figure 495 Frequency curve of annual peak flows, Deschutes River at Moody nr. Biggs

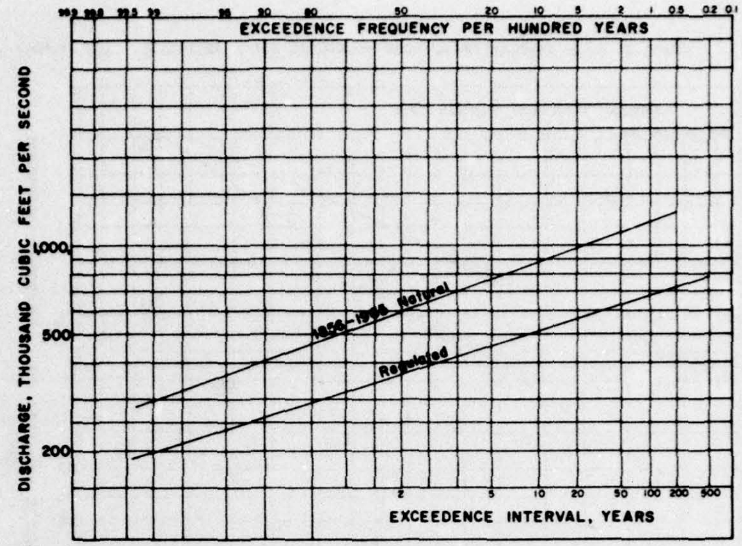


Figure 496 Frequency curve of annual peak flows, Columbia River at The Dalles

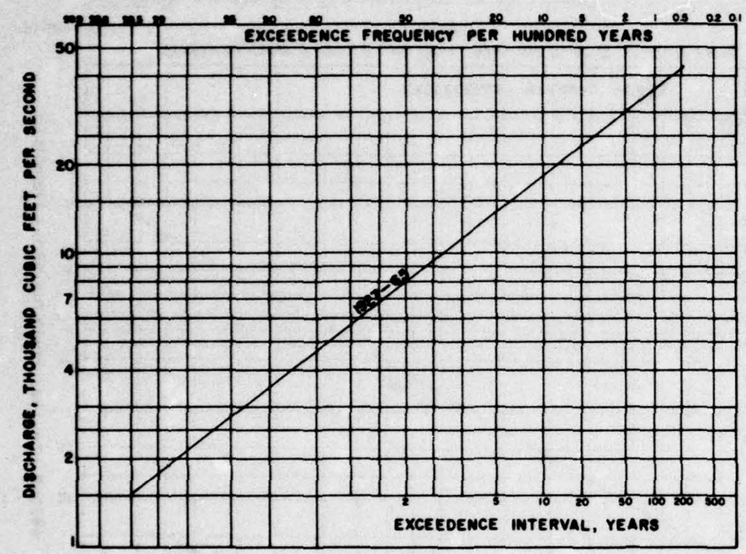


Figure 497 Frequency curve of annual peak flows, Klickitat River Nr. Pitt

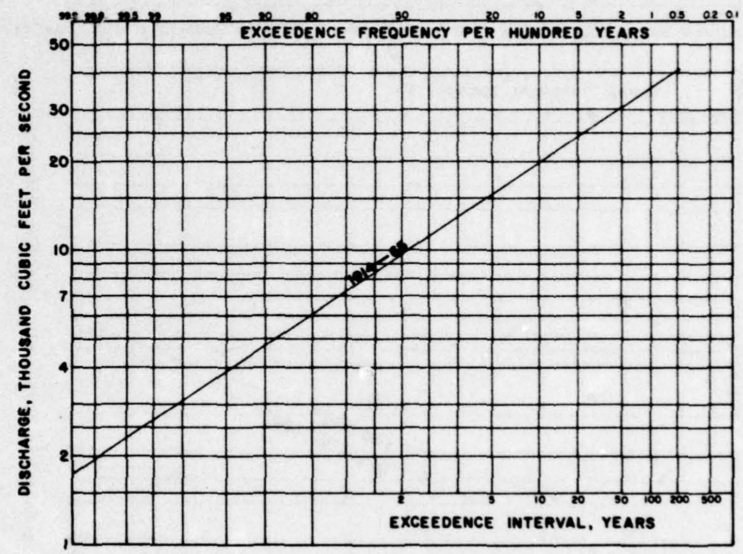


Figure 498 Frequency curve of annual peak flows, Hood River (Inc. PP&L Conduit) nr. Hood R.

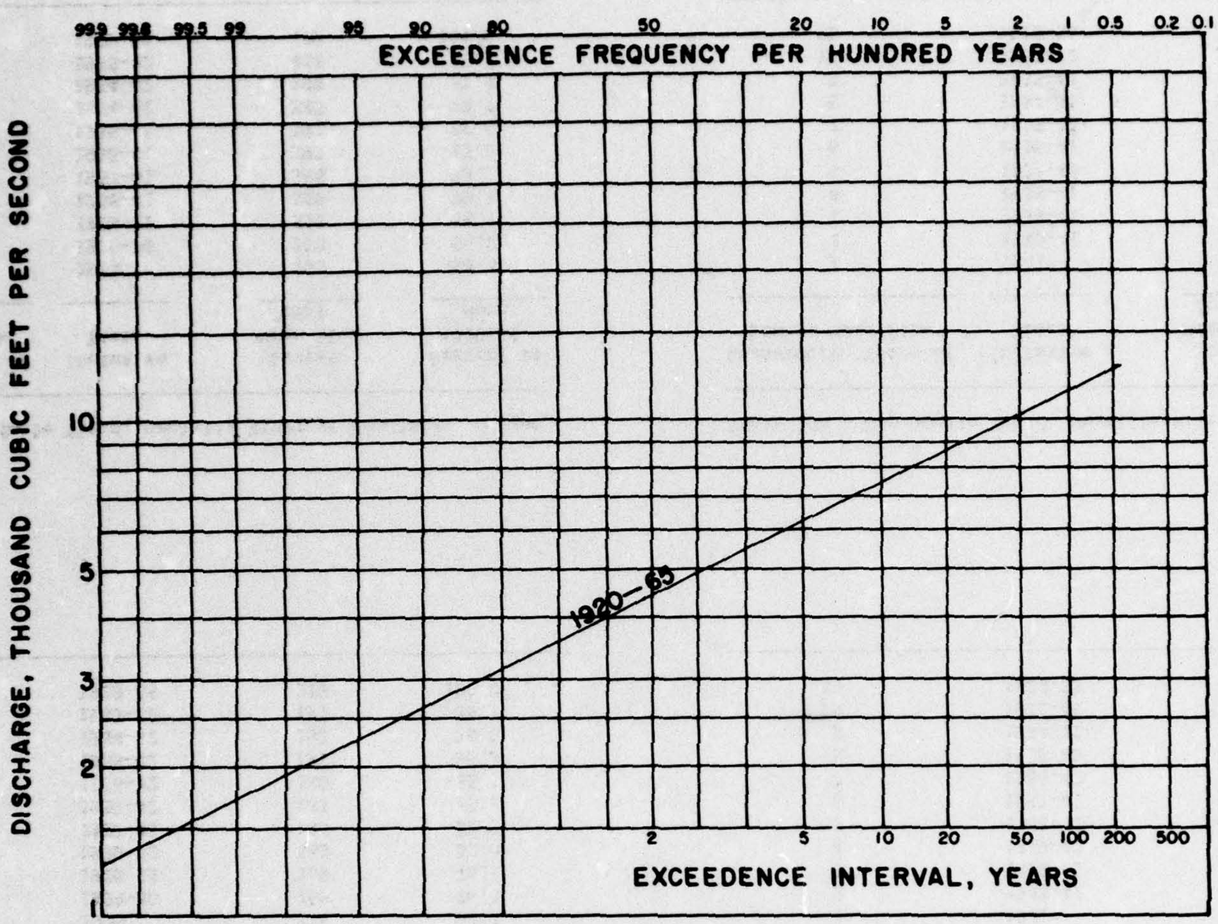


Figure 499 Frequency curve of annual peak flows, White Salmon River nr. Underwood

Table 263 - Dependable Yield, Walla Walla River Near Milton, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1929	136	61.3
2	1929-30	169	76.1
3	1929-31	169	76.1
4	1939-42	182	82.0
5	1937-41	184	82.9
6	1937-42	185	83.3
7	1936-42	189	85.1
8	1935-42	192	86.5
9	1934-42	192	86.5
10	1933-42	197	88.7
30	1929-58	222	100.0

Table 264 - Dependable Yield, Walla Walla River Near Touchet, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	237	42.7
2	1941-42	320	57.7
3	1929-31	369	66.5
4	1939-42	406	73.2
5	1938-42	432	77.8
6	1937-42	410	73.9
7	1936-42	431	77.7
8	1935-42	444	80.0
9	1934-42	453	81.6
10	1936-45	463	83.4
30	1929-58	555	100.0

Table 265 - Dependable Yield, Umatilla River at Pendleton, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	286	58.5
2	1929-30	319	65.2
3	1929-31	333	68.1
4	1938-41	390	79.8
5	1937-41	388	79.3
6	1936-41	397	81.2
7	1935-41	391	80.0
8	1934-41	385	78.7
9	1934-42	398	81.4
10	1933-42	416	85.1
30	1929-58	489	100.0

Table 266 - Dependable Yield, Umatilla River Near Umatilla, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	158	37.6
2	1940-41	226	53.8
3	1939-41	238	56.7
4	1938-41	254	60.5
5	1937-41	247	58.8
6	1936-41	256	61.0
7	1935-41	247	58.8
8	1934-41	246	58.6
9	1933-41	268	63.8
10	1933-42	292	69.5
30	1929-58	420	100.0

Table 267 - Dependable Yield, Willow Creek at Heppner, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	3.2	18.4
2	1934-35	3.5	20.1
3	1934-36	4.1	23.6
4	1934-37	6.1	35.0
5	1934-38	7.7	44.3
6	1934-39	7.7	44.3
7	1934-40	7.8	44.8
8	1934-41	8.0	46.0
9	1933-41	8.7	50.0
10	1932-41	9.9	56.9
30	1929-58	17.4	100.0

Table 268 - Dependable Yield, John Day River at Picture Gorge, Near Dayville, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	124	27.1
2	1934-35	154	33.6
3	1934-36	196	42.8
4	1934-37	220	48.0
5	1933-37	246	53.7
6	1932-37	279	60.9
7	1931-37	261	57.0
8	1930-37	248	54.1
9	1929-37	252	55.0
10	1929-38	287	62.7
30	1929-58	458	100.0

Table 269 - Dependable Yield, North Fork John Day River at Monument, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	484	39.8
2	1934-35	578	47.5
3	1934-36	651	53.5
4	1934-37	721	59.2
5	1933-37	805	66.1
6	1933-38	886	72.8
7	1933-39	884	72.6
8	1933-40	885	72.7
9	1933-41	900	74.0
10	1932-41	973	80.0
30	1929-58	1,217	100.0

Table 270 - Dependable Yield, John Day River at Service Creek, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	643	35.1
2	1930-31	744	40.6
3	1929-31	898	49.0
4	1934-37	1,025	56.0
5	1933-37	1,138	62.2
6	1930-35	1,148	62.7
7	1930-36	1,173	64.1
8	1930-37	1,179	64.4
9	1929-37	1,182	64.6
10	1929-38	1,273	69.5
30	1929-58	1,831	100.0

Table 271 - Dependable Yield, John Day River at McDonald Ferry, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	630	32.7
2	1930-31	761	39.5
3	1934-36	914	47.5
4	1934-37	1,042	54.1
5	1933-37	1,156	60.0
6	1929-34	1,224	63.6
7	1929-35	1,179	61.2
8	1929-36	1,182	61.4
9	1929-37	1,212	63.0
10	1929-38	1,313	68.2
30	1929-58	1,925	100.0

Table 272 - Dependable Yield, Deschutes River Below Lava Island, Near Bend, Oregon

Consecutive Years of Lowest Mean Flow Lowest	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	831	68.8
2	1931-32	869	71.9
3	1930-32	905	74.9
4	1929-32	941	77.9
5	1929-33	967	80.1
6	1930-35	984	81.4
7	1929-35	994	82.2
8	1929-36	1,003	83.1
9	1929-37	1,011	83.8
10	1929-38	1,033	85.5
30	1929-58	1,208	100.0

Table 273 - Dependable Yield, Deschutes River Below Bend

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1945	302	63.8
2	1941-42	319	67.4
3	1941-43	348	73.6
4	1945-48	355	75.1
5	1945-49	349	73.8
6	1945-50	361	76.3
7	1945-51	398	84.1
8	1941-48	404	85.4
9	1940-48	406	85.8
10	1940-49	396	83.7
30	1929-58	476	100.0

Table 274 - Dependable Yield, Crooked River Near Culver

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1,230	76.7
2	1930-31	1,255	78.2
3	1929-31	1,257	78.4
4	1929-32	1,318	82.1
5	1929-33	1,328	82.8
6	1929-34	1,313	81.9
7	1929-35	1,318	82.2
8	1929-36	1,337	83.4
9	1929-37	1,345	83.9
10	1929-38	1,388	86.5
30	1929-58	1,599	100.0

Table 275 - Dependable Yield, Deschutes River at Moody Near Biggs

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	3,940	75.6
2	1930-31	4,075	78.2
3	1929-31	4,187	80.4
4	1929-32	4,285	82.2
5	1929-33	4,334	83.2
6	1929-34	4,352	83.5
7	1929-35	4,399	84.4
8	1929-36	4,440	85.2
9	1929-37	4,448	85.4
10	1929-38	4,576	87.8
30	1929-58	5,186	100.0

Table 276 - Dependable Yield, Columbia River at The Dalles

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	127,495	74.3
2	1929-30	127,611	74.4
3	1929-31	127,752	74.5
4	1929-32	134,917	78.7
5	1929-33	145,398	84.8
6	1936-41	146,928	85.7
7	1935-41	148,859	86.8
8	1935-42	150,433	87.7
9	1937-45	150,513	87.7
10	1936-45	150,587	87.8
30	1929-58	171,332	100.0

Table 277 - Dependable Yield, Klickitat River Near Pitt

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	826	52.8
2	1930-31	947	60.7
3	1929-31	985	63.2
4	1929-32	1,102	70.7
5	1941-45	1,184	75.9
6	1940-45	1,196	76.7
7	1936-42	1,298	83.3
8	1939-46	1,229	78.8
9	1938-46	1,282	82.2
10	1937-46	1,286	82.5
30	1929-58	1,565	100.0

Table 278 - Dependable Yield, Hood River Near Hood River (Inc. PP&L Conduit)

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	582	55.6
2	1941-42	672	64.2
3	1940-42	713	68.2
4	1939-42	723	69.1
5	1938-42	818	78.2
6	1937-42	829	79.3
7	1936-42	854	81.6
8	1935-42	890	85.1
9	1934-42	948	90.6
10	1933-42	974	93.1
30	1929-58	1,072	100.0

Table 279 - Dependable Yield, White Salmon River Near Underwood

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	659	56.1
2	1929-30	725	64.3
3	1929-31	739	65.5
4	1929-32	849	75.3
5	1929-33	945	83.8
6	1939-44	886	78.5
7	1939-45	877	77.7
8	1939-46	909	80.6
9	1937-45	931	82.5
10	1938-45	938	83.2
30	1929-58	1,176	100.0

Table 280 - Dependable Yield, Columbia River at Bonneville Dam

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	131,353	74.1
2	1930-31	131,709	74.2
3	1929-31	131,725	74.3
4	1929-32	139,313	78.5
5	1929-33	150,233	84.7
6	1936-41	152,421	85.9
7	1936-42	154,419	87.0
8	1935-42	155,978	87.9
9	1937-45	155,940	87.9
10	1936-45	156,007	87.9
30	1929-58	177,400	100.0

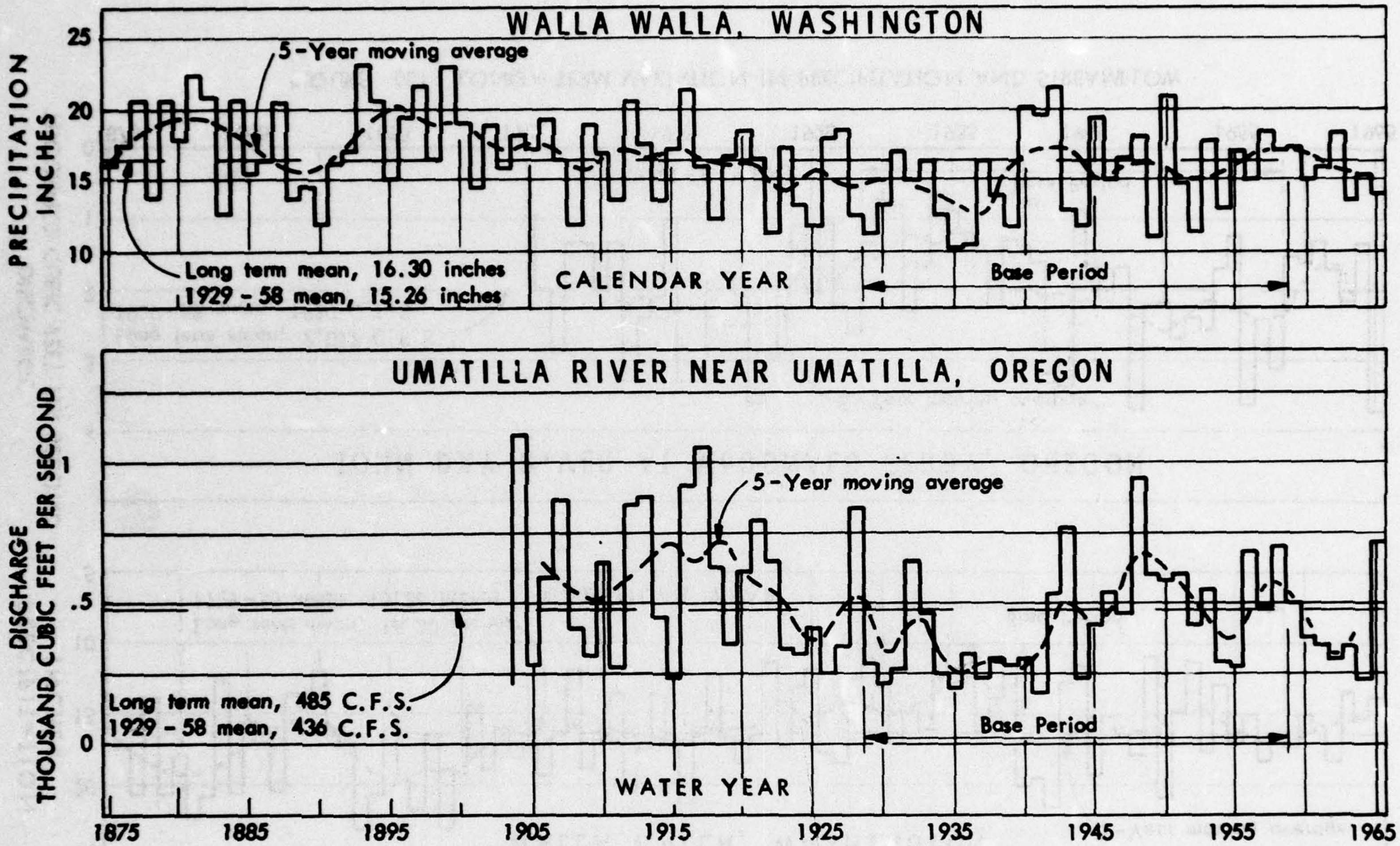


FIGURE 500 LONG - TERM VARIATION IN PRECIPITATION AND STREAMFLOW

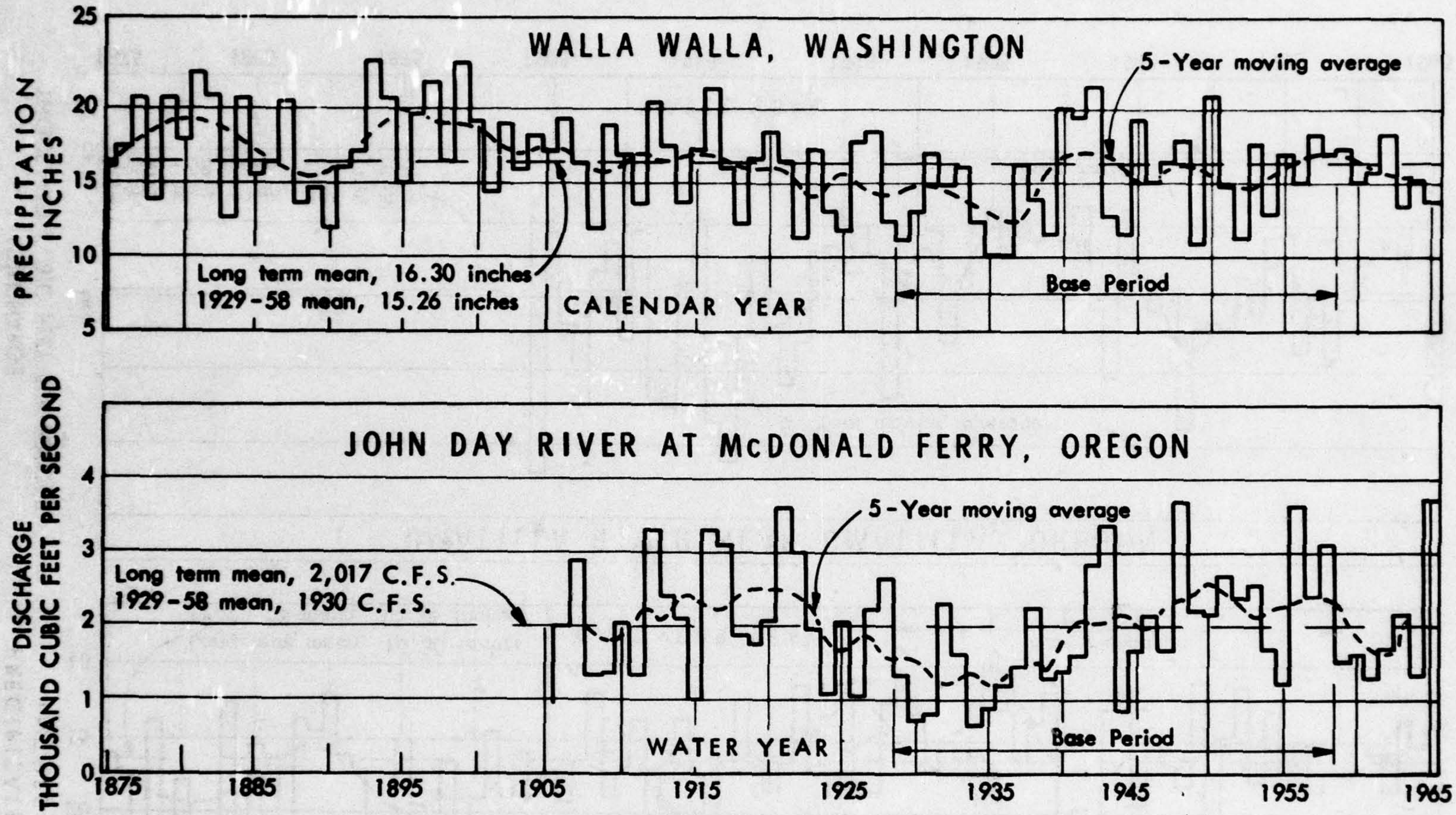


FIGURE 501 LONG-TERM VARIATION IN PRECIPITATION AND STREAMFLOW

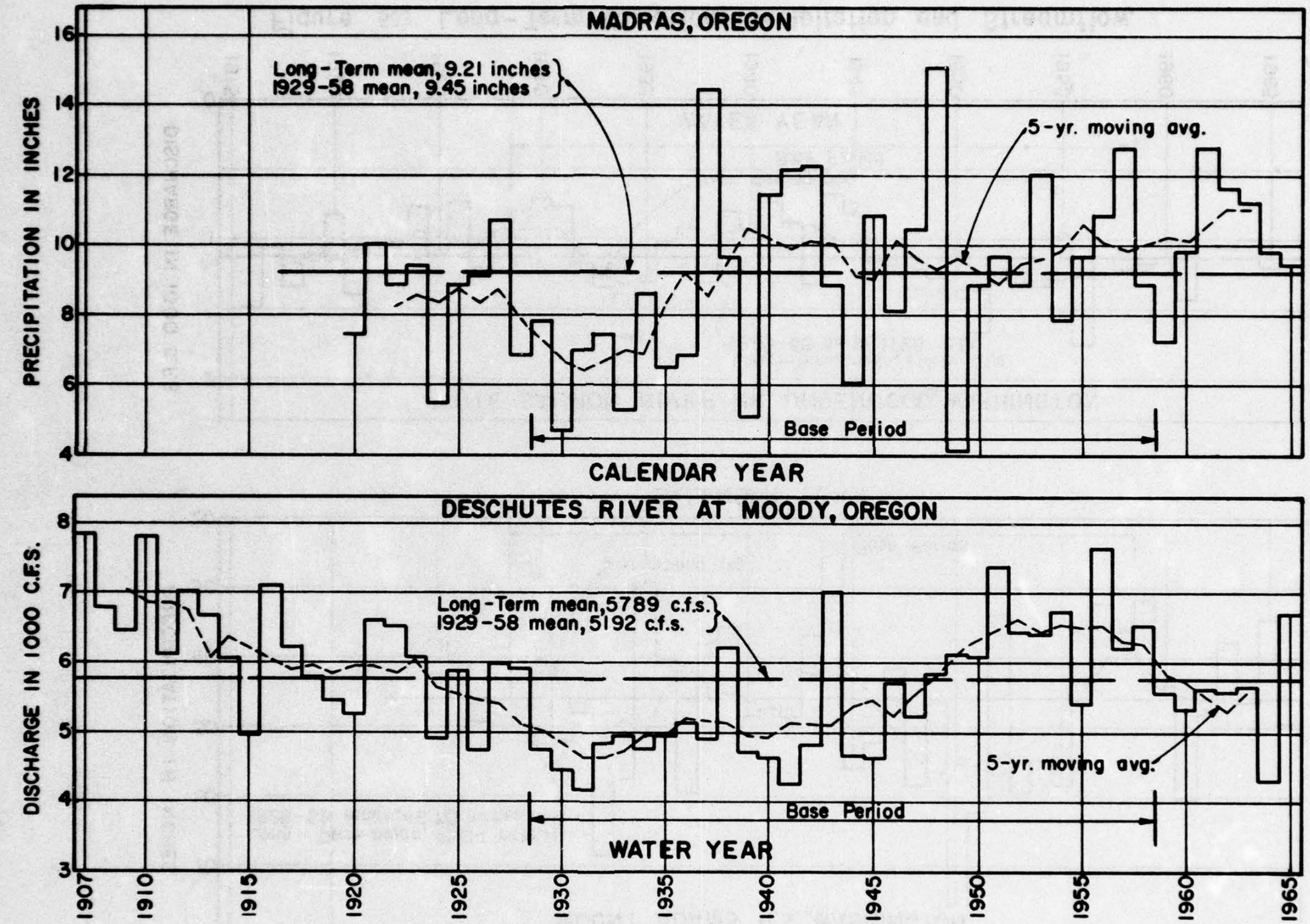


Figure 502 Long-Term Variation, Precipitation and Streamflow.

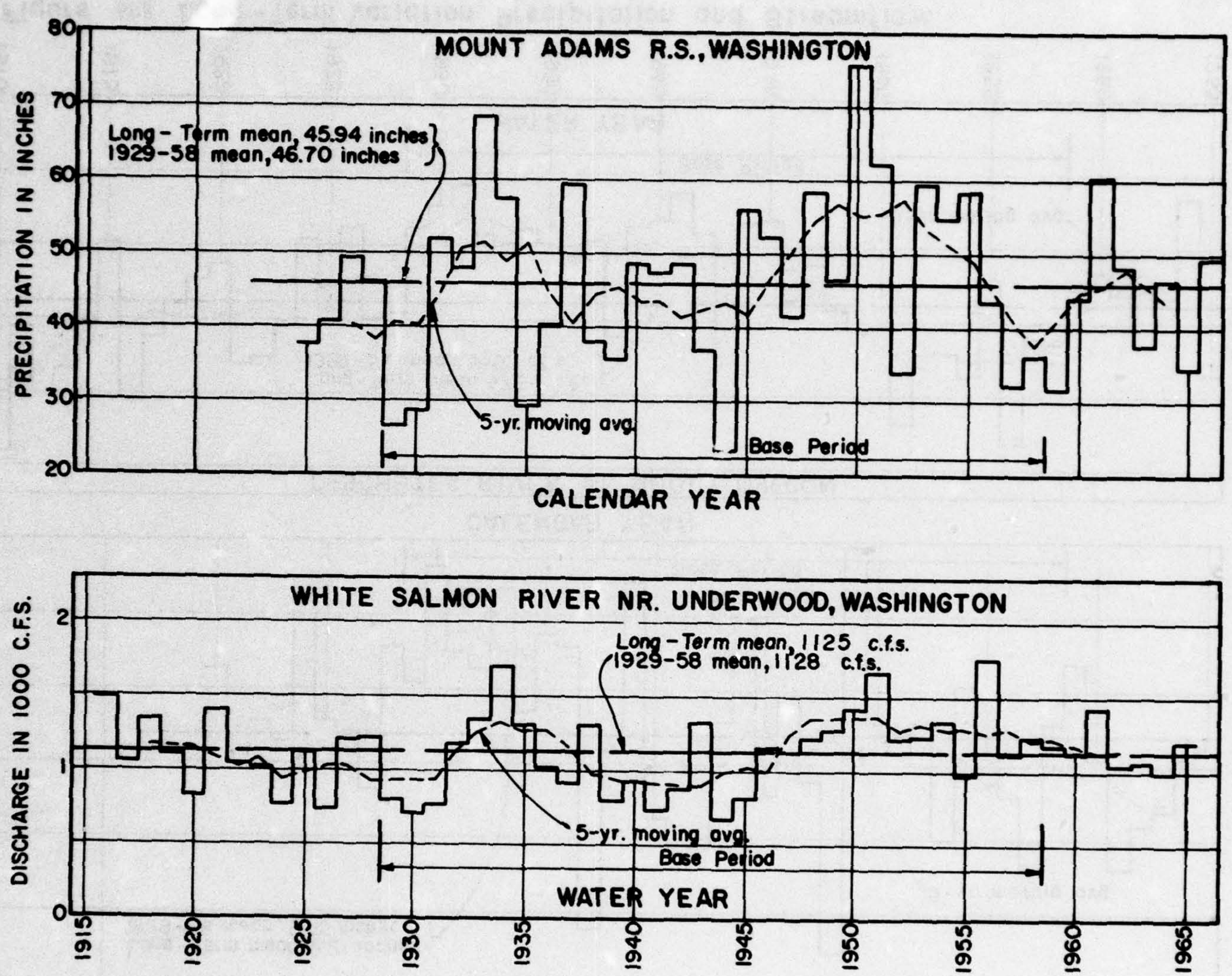


Figure 503 Long-Term Variation, Precipitation and Streamflow.

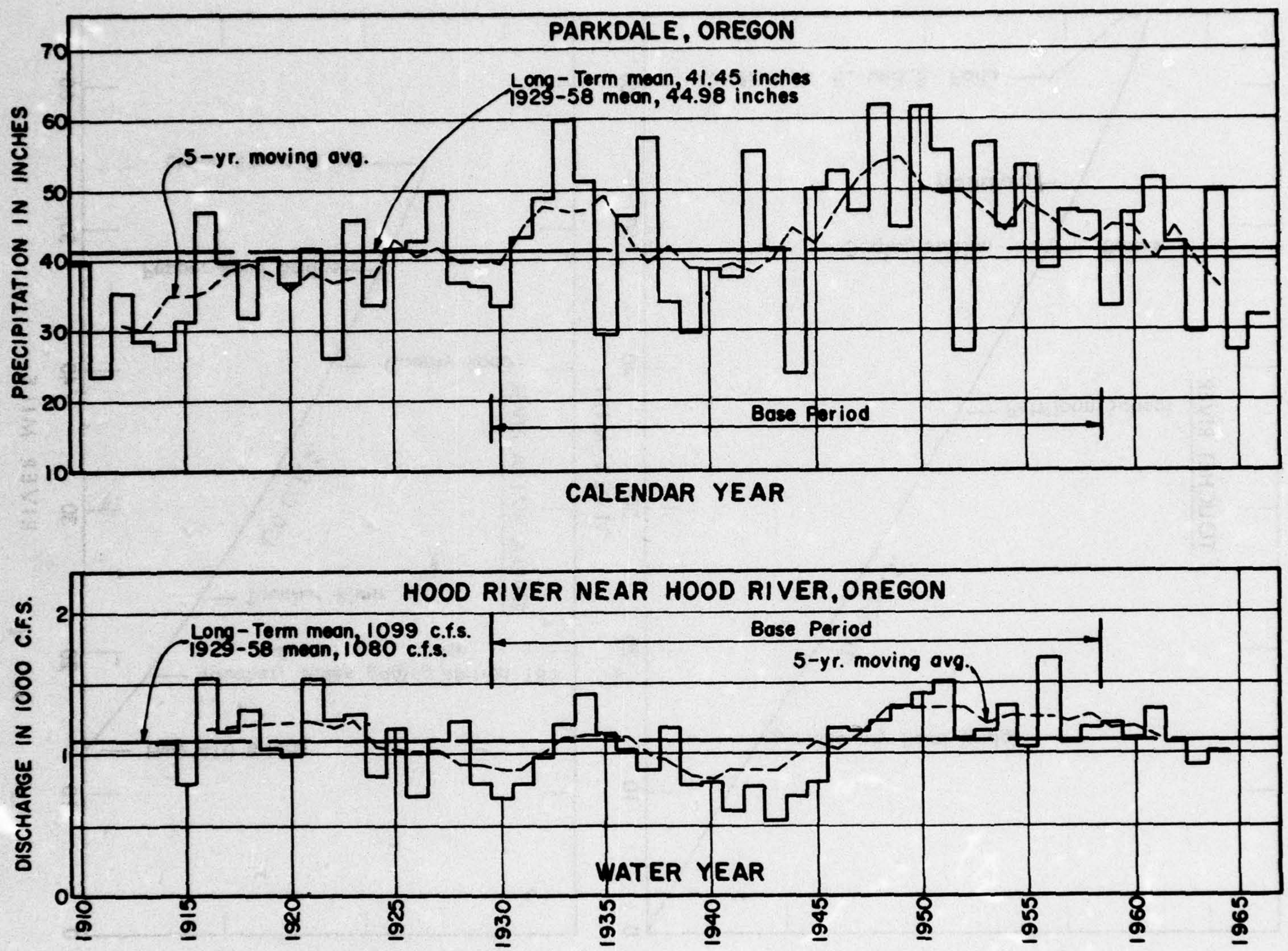


Figure 504 Long-Term Variation, Precipitation and Streamflow.

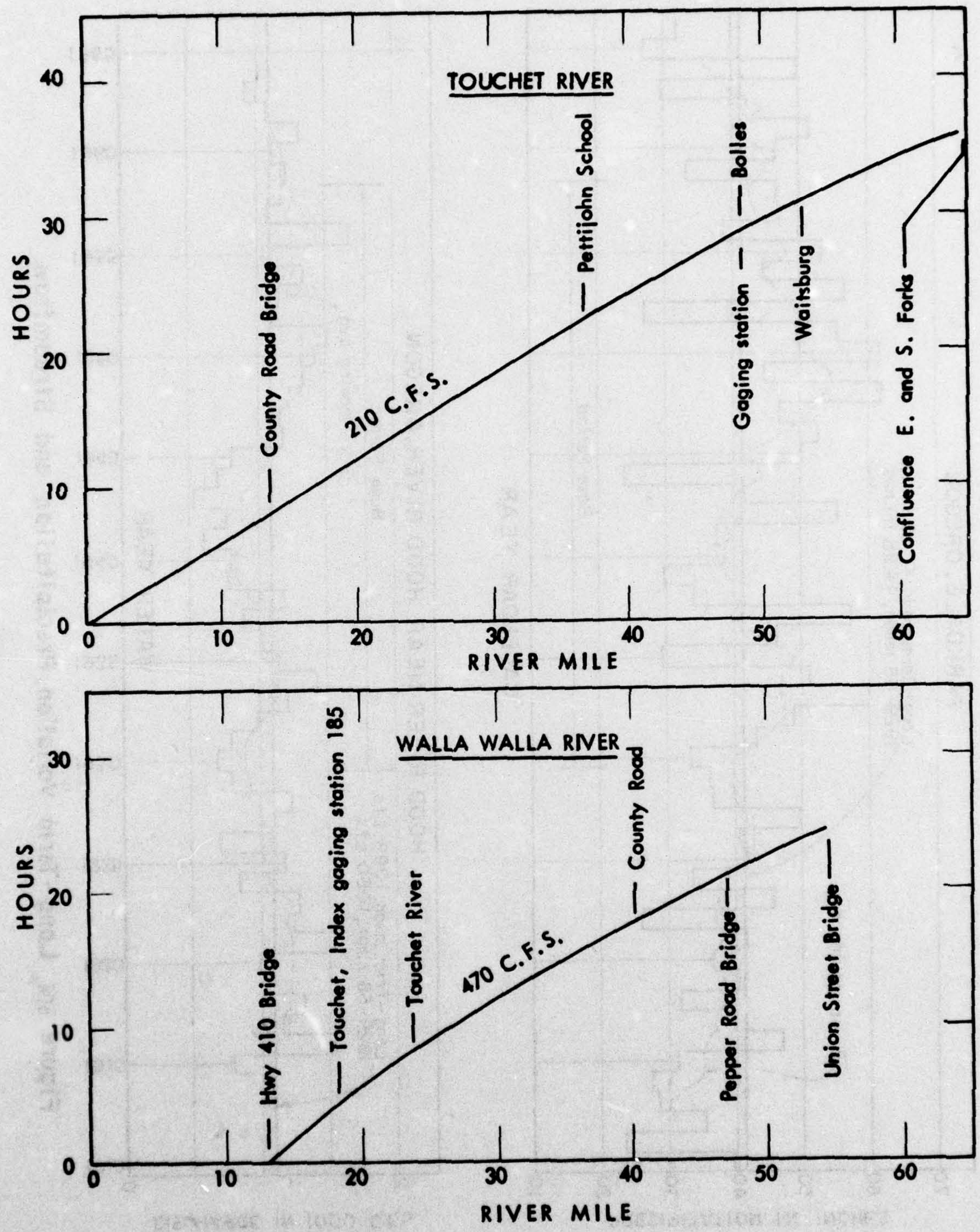


Figure 505 Time of travel Walla Walla and Touchet Rivers

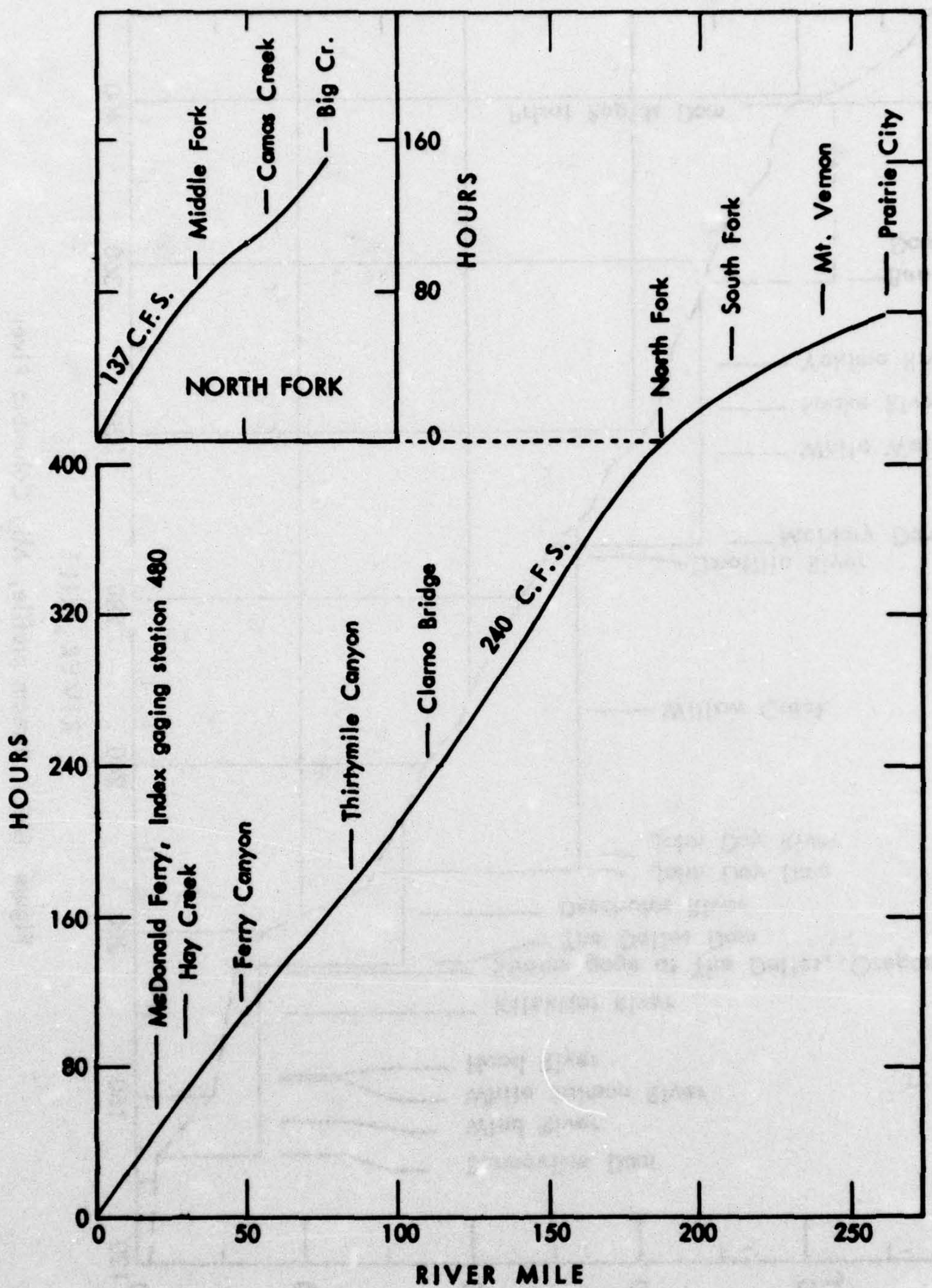


Figure 506 Time of travel, John Day River and North Fork

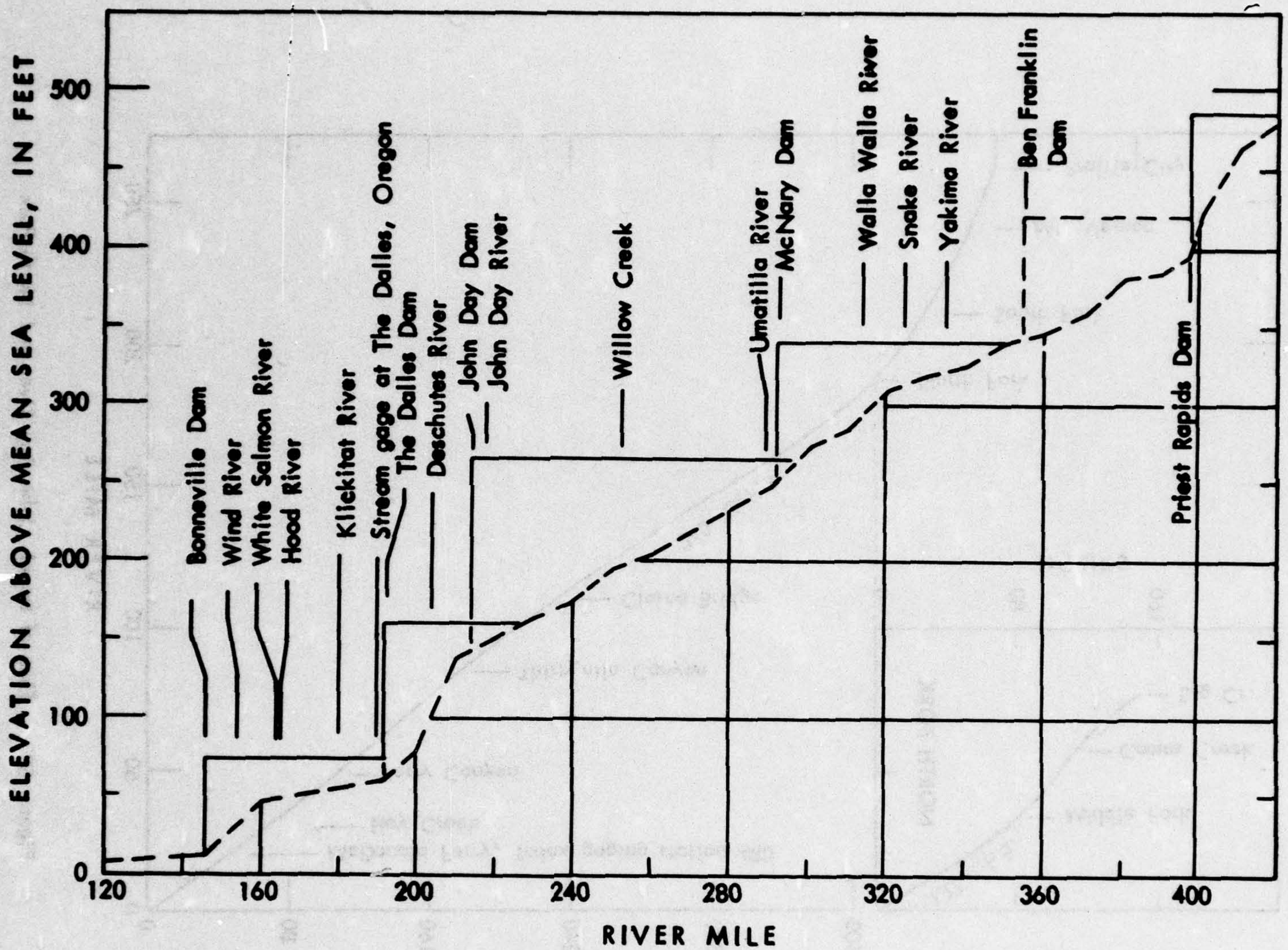


Figure 507 Stream profile, Mid Columbia River

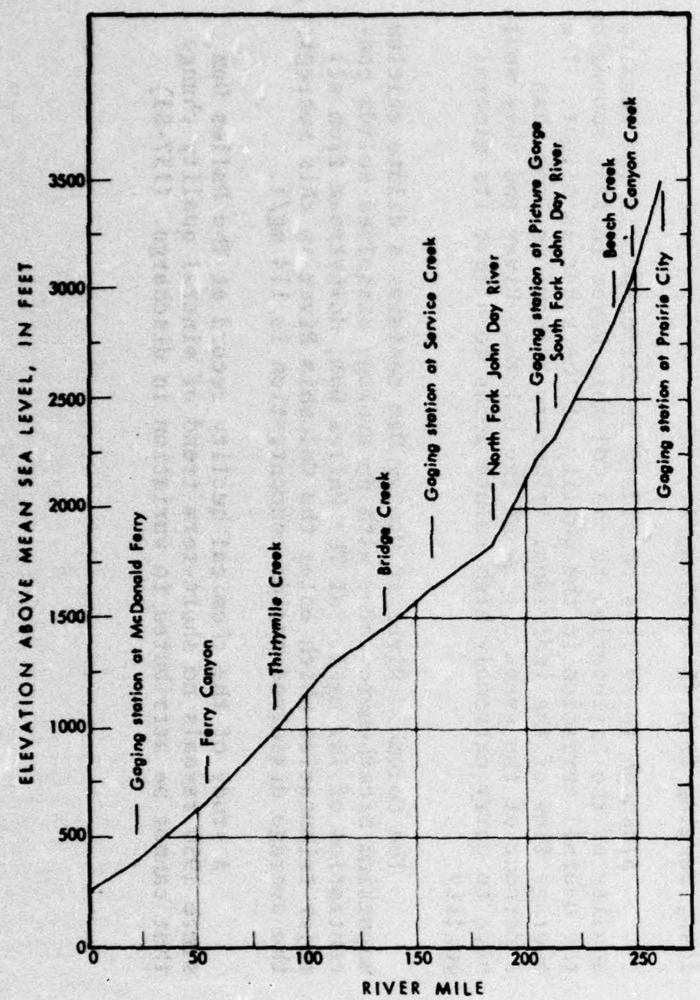


Figure 508. Stream profile, John Day River, Oregon.

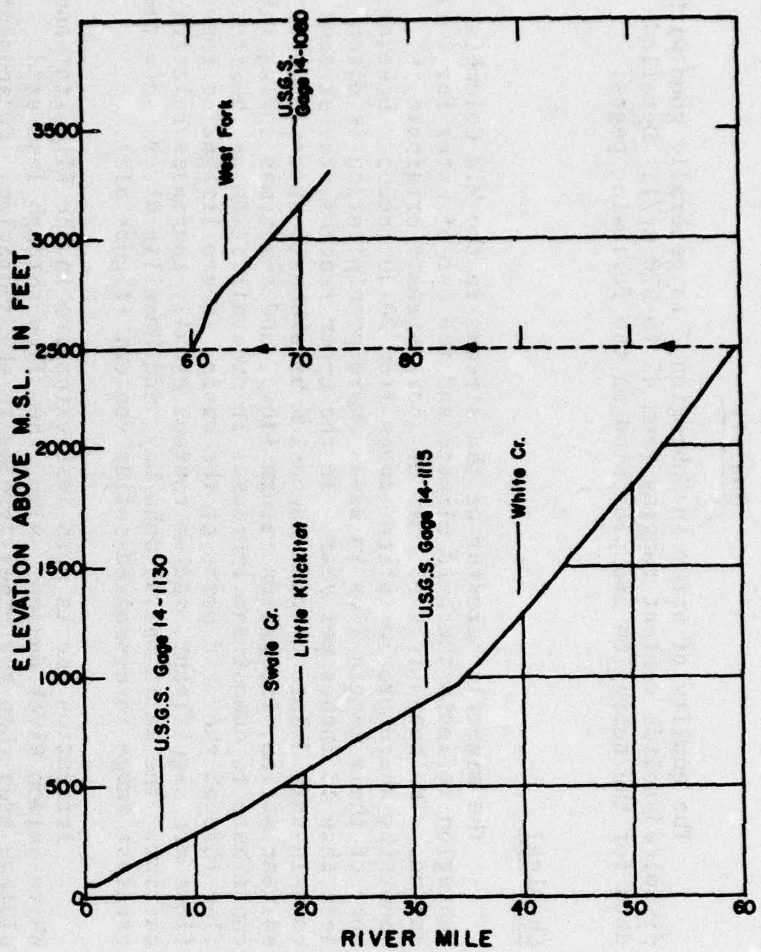


Figure 509. Stream profile, Klickitat River, Washington.

Quality

The quality of water in Subregion 7 is generally good with dissolved-solids content ranging from 45 to 570 mg/l. Detailed data for the subregion are presented on the following pages.

Chemical

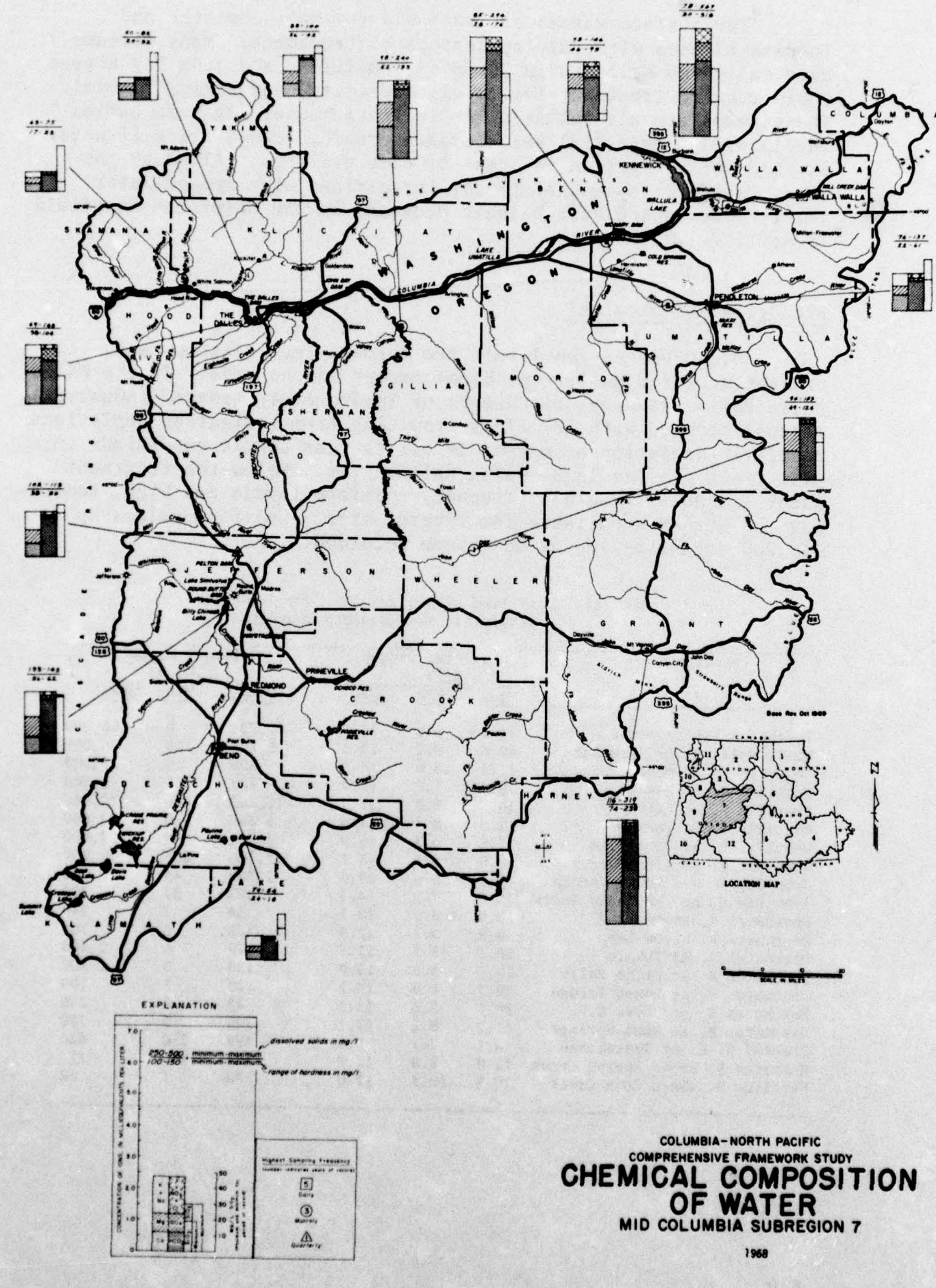
The mineral character of the streams in the Mid Columbia Subregion reflects the arid climate and the use of water for irrigation. The headwaters of most of these streams originate in mountains where precipitation ranges from 20-50 inches. However, most of their length lies in areas where precipitation is often less than 15 inches per year. In the upper reaches, the streams contain very dilute calcium magnesium bicarbonate waters. Natural solvent action, irrigation return flows, and sometimes spring inflow contribute to downstream increases in mineralization as the streams flow through the arid parts of the basin. Where irrigation return flows are significant, sodium content usually increases relative to calcium. The Walla Walla, John Day, and Umatilla Rivers show the greatest range in dissolved-solids content (figure 510).

Irrigation use is much less extensive in the Klickitat and White Salmon River Basins. Also, they flow through less arid plateau area than the other streams in the subregion. Consequently, their average dissolved-solids content at the mouth is considerably less, ranging from 45 to 85 mg/l.

Although there is a considerable difference in the chemical quality of the tributaries to the Columbia River in this subregion, the overall variation in the quality of the river is slight. The average flow of the individual tributary streams is less than 3 percent of the average flow of the Columbia River and they would have to carry extremely high solute loads to affect its mineral quality.

The Columbia River at McNary Dam contains a dilute calcium magnesium bicarbonate water with an average dissolved-solids concentration of 109 mg/l. At The Dalles Dam, downstream from all major tributaries which enter the Columbia River in this subregion, the average dissolved-solids concentration is 114 mg/l.

A study of the chemical quality record at The Dalles Dam since 1950 reveals no short-term trend of mineral quality change that cannot be attributed to variation in discharge. (137-51)



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

MID COLUMBIA SUBREGION 7

1968

FIGURE 510

The surface waters are suitable for most domestic and industrial uses with varying degrees of treatment. Many streams, especially the Walla Walla, Crooked, Umatilla, and John Day Rivers would require treatment for color, turbidity, and silica removal. The streams are all suitable for irrigation use. In some basins (Walla Walla, Umatilla) salt balance problems could arise if water is used for irrigation in areas of poor drainage. Although the water is of suitable quality for irrigation, high ground-water levels have caused salt balance problems in the Hermiston-Stanfield area. (137-17)

Biological-Biochemical

Dissolved oxygen levels are normally satisfactory and present no water quality problems except in one area. In the Walla Walla Basin, seasonal discharges of inadequately treated industrial wastes, coupled with low flows resulting from irrigation depletions, result in depletion of oxygen levels to near septic conditions in Mill Creek and the lower Walla Walla River. Below the treatment plant and downstream near Touchet, coliform levels are high, rendering the stream unsuitable for several uses. Coliform values up to 150,000 organisms/100 ml have been recorded.

Table 281. Dissolved Oxygen and Coliform Organisms Densities, Mid Columbia Subregion

Location	Dissolved Oxygen mg/l			Coliform Organisms /100 ml		
	Mean	Min	Max	Mean	Min	Max
Touchet R. at Dayton	11.1	9.1	12.7	72,281	0	460,000
Walla Walla R. nr. Touchet	10.6	8.2	14.5	5,525	230	46,000
Columbia R. at McNary Dam	11.1	8.6	14.5	826	0	15,000
Umatilla R. at Hwy 11	10.4	7.9	13.2	247	13	1,300
Umatilla R. at Reith	10.5	8.2	13.7	15,199	450	70,000
Umatilla R. at Yoakum	11.6	8.4	14.3	3,847	240	24,000
Umatilla R. nr. Umatilla	11.8	9.3	16.0	2,281	60	7,000
John Day R. nr. John Day	9.9	3.3	13.1	7,306	600	70,000
John Day R. nr. Mount Vernon	10.1	6.6	13.2	2,269	45	7,000
John Day R. nr. McDonald Ferry	11.0	7.2	14.4	253	21	700
Deschutes R. above Bend	10.0	8.5	12.3	44	2	240
Deschutes R. below Bend	9.8	8.3	12.3	123	6	700
Deschutes R. at Tumalo	10.5	8.7	12.7	179	6	2,400
Deschutes R. at Cline Falls	10.5	8.0	13.0	130	5	700
Deschutes R. at Lower Bridge	10.7	8.0	13.2	120	5	700
Deschutes R. nr. Cove S.P.	10.7	8.6	12.5	43	6	240
Deschutes R. at Warm Springs	11.3	9.2	13.2	125	2	700
Crooked R. E. of Terrebonne	8.1	7.1	8.6	490	230	620
Metolius R. above Spring Creek	11.0	8.9	12.7	154	130	174
Metolius R. above Cove Creek	10.8	10.3	11.6	20	5	62

High bacterial densities have been found below other population concentrations, such as the upper reaches of the John Day, throughout the subregion. High counts have also been found on occasion in unpopulated areas, indicating that soil bacteria and animal populations can have a decided effect on the indicated levels of coliform bacteria.

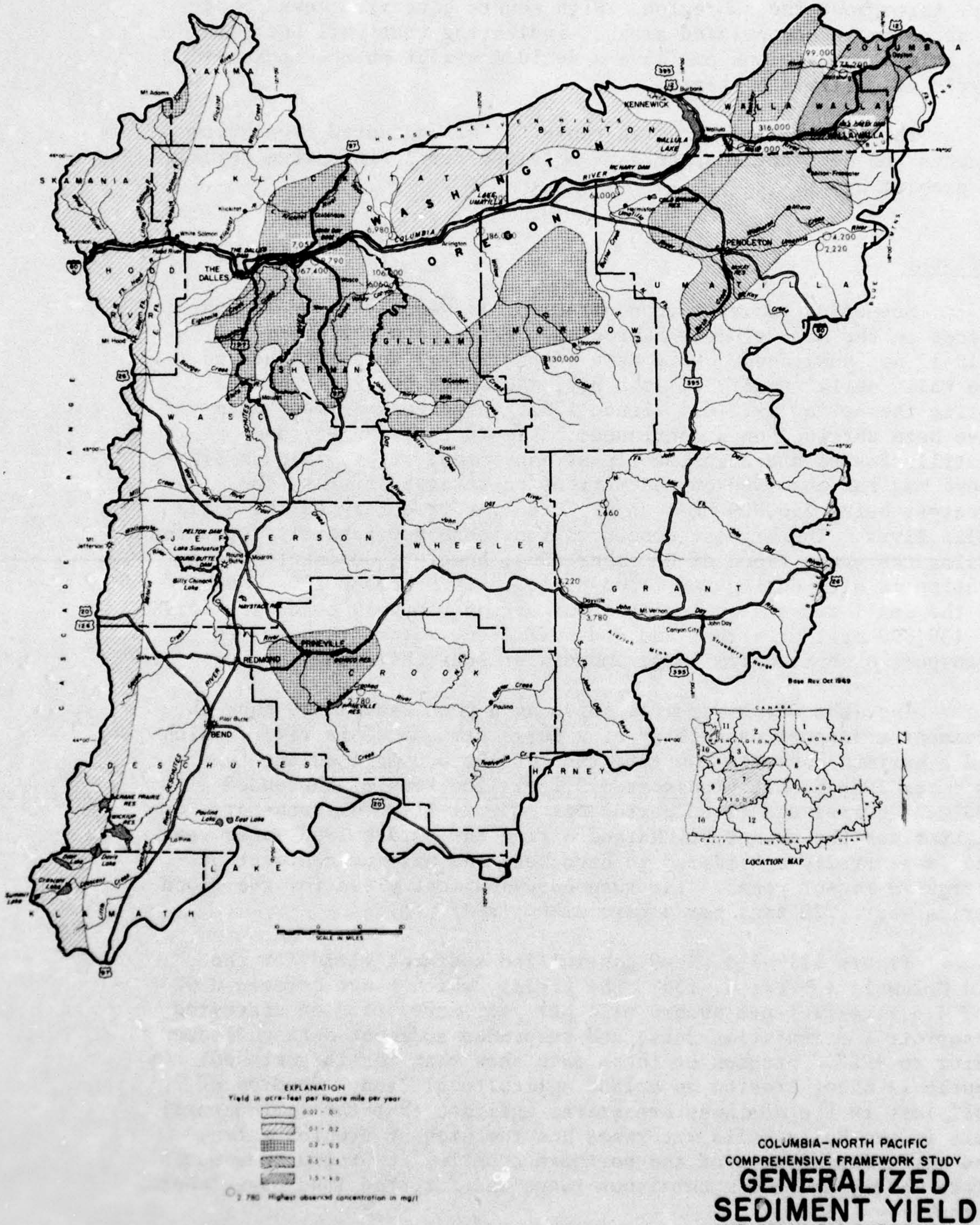
The information shown in table 281 was gathered from State sources and does not include data obtained during intensive surveys of problem areas.

Sediment

Suspended-sediment concentration has been measured at many places in the Mid Columbia Subregion. Early data collected in 1910-12 are published. More data (unpublished) were obtained in the Walla Walla, Umatilla, John Day, and Deschutes River Basins during the period 1950-61. Since 1962, suspended-sediment data have been obtained on a continuous basis in the John Day and Umatilla Basins and occasionally at many other sites. Figure 511 shows maximum observed concentrations on several streams, the greatest being 316,000 mg/l on Dry Creek, a tributary to the Walla Walla River. The highest concentrations observed generally occurred during the great flood of December 1964; however, sediment concentration is high during any flood period. In December 1964, some of the small streams in northcentral Oregon had peak concentrations of 135,000 mg/l or higher and had sufficient water discharge to transport exceptionally large amounts of sediment. (204)

The John Day River will serve as a good example to show the sediment transport capability of a large stream. This river, which had a maximum observed concentration of 106,000 mg/l during the December 1964 flood, transported 9.2 million tons of suspended sediment during the flood period December 21-31. This was more than eight times the amount discharged during the entire 1963 water year and is generally considered to have been the maximum sediment discharge in recent years. The suspended-sediment yield for the flood period was 1,220 tons per square mile. (204)

Figure 511 also shows generalized sediment yield for the Mid Columbia Subregion. (30) The yields, which range between 0.02 and 4.0 acre-feet per square mile per year were based on scattered reservoir sedimentation data, and suspended-sediment data collected prior to 1953. Studies of these data show that the largest sediment source is sheet erosion on upland agricultural land. Studies of soil loss in the northwestern states indicate that the agricultural belt in the Walla Walla watershed has the highest erosion rates, the agricultural area of the northern counties in Oregon more moderate rates, and the mountainous range and forested land have lower rates.



COLUMBIA–NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

MID COLUMBIA SUBREGION 7

1968

FIGURE 511

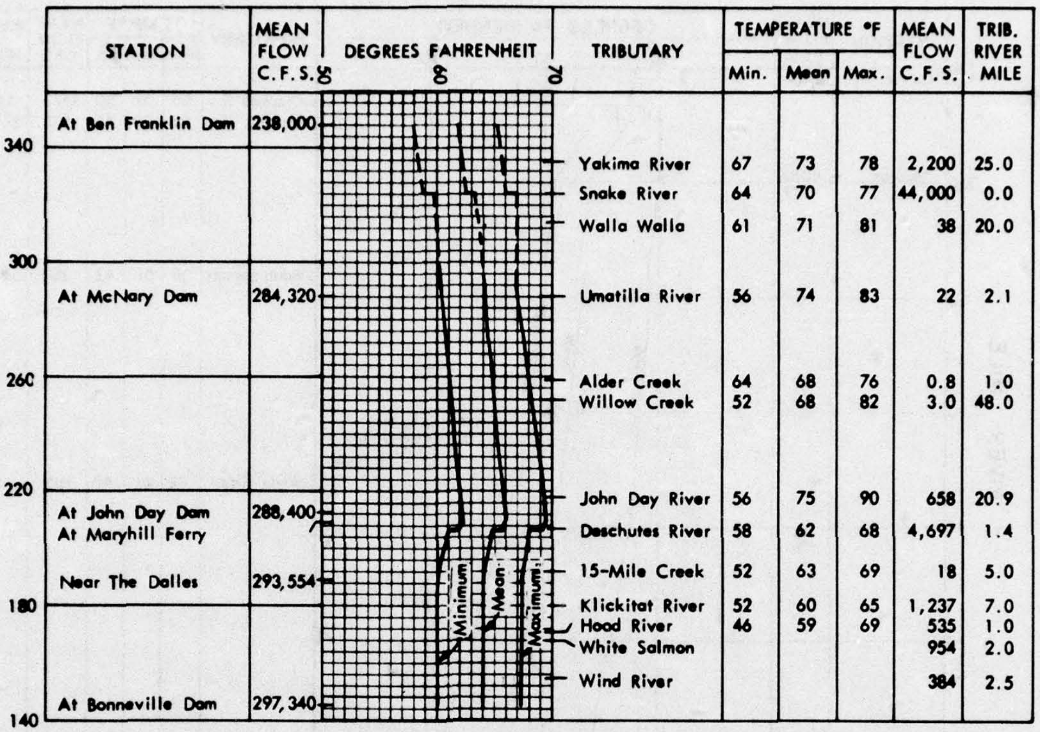


Figure 512. Water temperature profiles for July, Mid-Columbia River, 1944-1965.

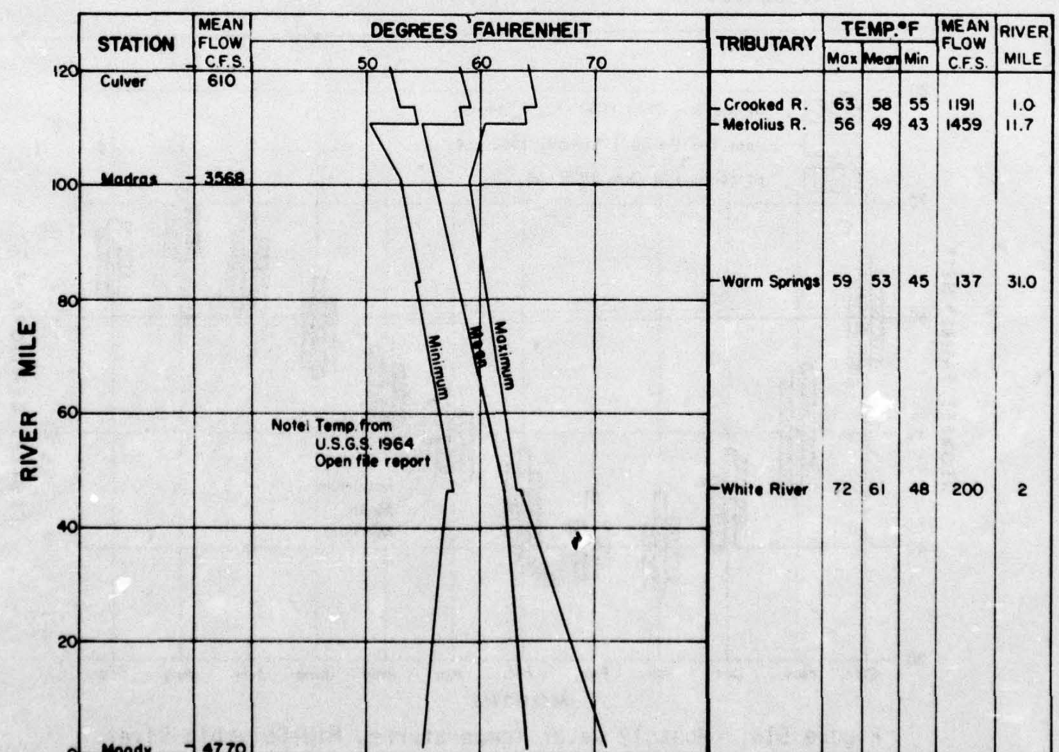


Figure 513. Water temperature profiles for July, Deschutes River Basin, 1952-62.

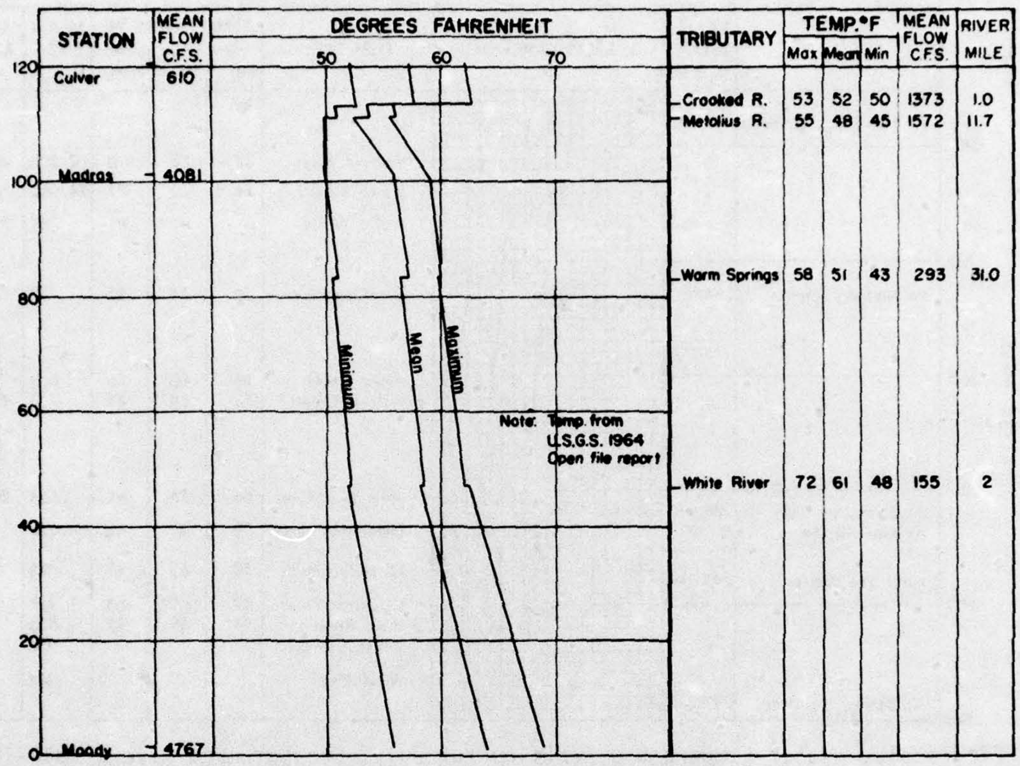


Figure 514. Water temperature profiles for August, Deschutes River Basin, 1952-62.

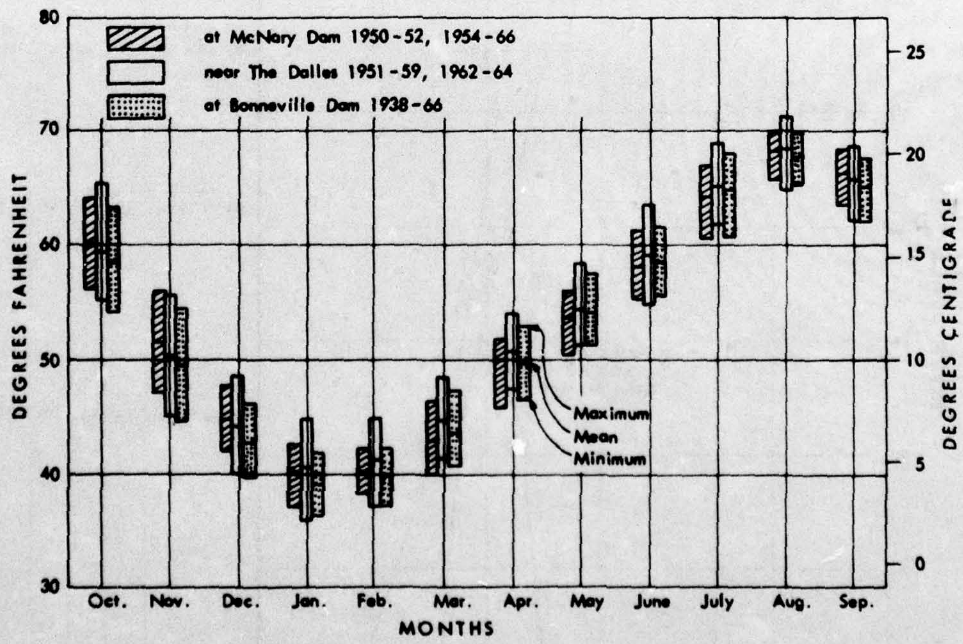


Figure 515. Monthly water temperatures, Mid-Columbia River.

Water Temperature

Sufficient water temperature data have been collected to construct profiles for the Columbia and Deschutes Rivers. Figure 512 shows maximum, minimum, and mean temperature profiles for the Mid Columbia River. Figures 513 and 514 show the profiles for July and August, respectively, for the Deschutes River. In addition to temperature versus river mile, the temperatures are given for entering tributaries, and discharges are noted. The cooling effect of the tributaries on the mainstem is clearly evident by the sharp drops in the profile.

Maximum temperature for 22 years in the Columbia River from mile 350 to mile 210 rose from 65°F. to 69 1/2°F. and cooled to 67°F. by mile 150 during July. The range from minimum to maximum during the month was 11 1/2°F.

Maximum temperature for 11 years from mile 120 to the mouth in the Deschutes River varied from 59°F. to 71°F. during July, and from 56°F. to 69°F. during August. The range from minimum to maximum during each month was about 20°F.

Monthly temperatures throughout the year are shown for three Columbia River stations over periods of 12 to 29 years on figure 515. These vary from a high of 71°F. in August to a low of 36°F. in January.

GROUND WATER

Three aquifer units are capable of furnishing moderately large to large supplies of water in Subregion 7. Two of these, the alluvial deposits (Qal) and the Miocene volcanic rocks (Tmv), including basalt of the Columbia River Group, have been utilized extensively for ground-water supplies. The third unit, late Tertiary and Quaternary volcanic rocks (QTv), crops out chiefly in high plateaus or mountainous areas and has been utilized much less extensively. Two other units, the Tertiary sedimentary deposits (Ts) and the older Tertiary volcanic and associated sedimentary rocks (Tvs), generally yield small quantities of water but yield moderate to moderately large supplies at a few places.

Water quality usually is good to excellent. Dissolved solids rarely exceed 500 mg/l.

Several reports give the results of ground-water investigations which have been made in various parts of the subregion. (52, 101, 117, 129, 148, 178) A few additional reports include some information on ground water. (108, 110, 112, 113, 141)

Aquifer Units and Their Hydrologic Characteristics

Six aquifer units have been delineated in the subregion and are shown on figure 516. West of the 121st meridian in Oregon, the boundaries are based on the geologic map of Oregon (202); in Washington, boundaries are based on the geologic map of Washington (54). Various other maps were used for compilation of the map for that part of Oregon east of the 121st meridian. (7, 51, 52, 110, 112, 186)

The alluvial deposits (Qal) consist chiefly of silt, sand, and gravel deposited in stream channels and on flood plains. Also included are lake deposits of various types: sand, silt, and clay deposited on lake bottoms; gravel and sand in deltas; beach and bar deposits formed at the margins of the lakes. Some eolian sand and silt may also be included. All of these deposits are lenticular and discontinuous. In most valleys and basins erosion has formed terraces and benches in the alluvial deposits. The medium to coarse sand and gravel are very porous and permeable and yield moderate to very large quantities of water, the yields being related to the saturated thickness of the deposits. Yields of 100 to 1,000 gpm and specific capacities of 5 to 50 gpm per foot of drawdown are common.

The volcanic rocks of Tertiary and Quaternary age (QTv) are chiefly basaltic to andesitic flows, tuff and tuff breccia, pumice and scoria, and volcanic ash. They occur as broad domes, cones, and intracanyon flows. The deposits are moderately to highly porous and permeable and are capable of yielding large quantities of water. Where 50 to 100 feet of permeable materials are saturated, wells yield 1,000 to several thousand gallons a minute with a few feet of drawdown. However, at some places the water table is many hundred feet below the land surface, which increases the cost of utilizing the water.

The sedimentary strata (Ts) are chiefly Tertiary (Miocene to Pliocene) age, but may include some early Pleistocene deposits. They are chiefly fine-grained semiconsolidated deposits such as siltstone, mudstone, tuff, and shale, but include some sandstone and conglomerate beds. Generally, the deposits occur as partly dissected basin fill in or near the major valleys. The fine-grained strata commonly yield little or no water, but the sand and gravel yield small to moderate supplies. Yields of 100 to 200 gpm can be obtained from better wells, generally with large drawdowns.

The Tertiary volcanic rocks (Tmv), chiefly Miocene, include the Columbia River Group (Tcr) of Subregions 2, 3, and 6, and similar basalts that have been mapped under other formational names. The basalt forms a great sequence of flood-type lavas with a total thickness of several thousand feet. Permeable zones occur

at and adjacent to the contacts between successive flows, and moderate to large yields are obtained where several interflow zones are penetrated. Yields of better wells range from a few hundred to several thousand gallons per minute.

The older volcanic and sedimentary rocks (Tvs) include a variety of rocks ranging in age from Eocene to Miocene(?). They are chiefly silicic volcanic rocks and interbedded sedimentary strata. Consolidation, cementation, and secondary mineralization have greatly reduced the primary porosity and permeability. Some water occurs in and moves through joints and other fractures. At most places wells in this unit will furnish only small yields sufficient for domestic and stock use. Where coarser-grained phases are encountered or at places where fracturing is great, moderate yields may be obtained.

All pre-Tertiary rocks (pT) are grouped into one aquifer unit. A great variety of sedimentary and volcanic rocks, plus a few areas of intrusive igneous rocks such as granodiorite, diorite, and gabbro, are included. Most of the sedimentary and volcanic rocks have been strongly folded and some strata have been slightly to greatly metamorphosed. The common characteristic of the pre-Tertiary rocks is that they are compact, relatively hard, and have low porosity and permeability but, generally, they have a moderately deep-weathered soil and subsoil that is considerably more porous and permeable than the underlying rock. Yields of most drilled wells are small but many small springs discharge from the overburden, and shallow dug wells generally yield supplies adequate for domestic and stock use. The chief hydrologic importance of the unit is to supply water, from fairly short-term storage, that maintains the base flow of streams.

Brief descriptions of the aquifer units, their general hydrologic characteristics, and the quality of the water yielded by them are given in table 282. The general availability of ground water is shown on a map, figure 517. For maximum usefulness that map, and the aquifer-unit map, figure 516, should be used together.

Because of lack of data, some areas underlain by volcanic rocks (Tmv) and sedimentary rocks (Ts) are shown as "unknown" on figure 517. Probably at many places wells would furnish moderate to moderately large yields. Much of the area of the younger volcanic rocks (QTv) also is shown as "unknown" but probably would furnish moderately large to large yields at many places where the depth to water is not too great to make it uneconomical.

Table 282 - Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 7

Map Symbols and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qal: Stream alluvium, and basin fill of fluvial, lacustrine and eolian origin. Chiefly Pleistocene and Holocene in age, but may include some Pliocene deposits.	Unconsolidated to slightly consolidated, lenticular strata of gravel, sand, and silt deposited in stream channels and on flood plains. Includes some fine-grained lacustrine deposits.	Coarser and better-sorted deposits of sand and gravel are porous and permeable and transmit and yield water readily, the amount of water being related to the thickness of the zone of saturation of the porous and permeable zone. Moderate to large yields common.	Dissolved solids generally less than 350 mg/l. Water generally moderately hard to hard.
QTv: Volcanic flows, flow breccia and interbedded pyroclastic and water-laid deposits. Chiefly Pleistocene to Holocene in age, but includes some Middle to late-Pliocene rocks.	Chiefly open textured, light to dark gray; olivine basalt and basaltic andesite flows also includes tuff and tuff breccia; platy porphyritic andesite; widely spread deposits of unconsolidated white to buff ash and pumice; gray to red basaltic scoria.	Some flow units and interflow zones, scoria, pumice, granular ash, breccia are porous and very permeable. Where 50 to 100 ft of permeable materials are saturated, wells yield 1,000 to several thousand gallons per minute with a few feet of drawdown.	Few data available. Dissolved solids generally less than 300 mg/l. Water soft to hard.
Ts: Fluvial and lacustrine deposits. Includes strata of Miocene to early Pleistocene (?) age.	Thin to medium bedded, semiconsolidated sandstone, sandy shale, conglomerate, tuff, and welded tuff. Generally forms terraces and partly dissects basins along major drainages.	Shale, siltstone, massive tuffs generally yield little water but coarser-grained zones are moderately porous and permeable, and yield small to moderate quantities of water. Well yields of 100 to 200 gpm can be obtained with large drawdowns.	Few data available. Dissolved solids probably generally less than 500 mg/l, water moderately hard to very hard. Sodium may be high in some wells.
Tmv: Lava flows and associated pyroclastic rocks. Includes Columbia River Group and similar volcanic rocks of Miocene and lower Pliocene age.	Thick, columnar and irregular-jointed dark gray to black basalt and basaltic andesite. Generally fine grained, occasionally porphyritic. Flows spread widely from fissures, are 20 to 100 ft thick.	Individual flow dense, has low porosity and permeability. Permeable zones are formed where upper surface of flow is incompletely filled by succeeding flow. Where several permeable interflow zones are penetrated, wells yield a few hundred to several thousand gallons a minute.	Dissolved solids generally less than 400 mg/l. Water soft to hard, hardness of water rarely more than 180 mg/l. Temperatures 55° to 75°F, increasing with depth.
Tvs: Volcanic and associated sedimentary rocks. Includes John Day, Clarno Fm., and similar rocks of Eocene to lower Miocene age.	Chiefly silicic volcanic rocks and interbedded water-laid deposits of volcanic materials. Includes white to buff tuffaceous siltstone, tuff, and conglomerate; rhyolitic, andesitic, dacitic and basaltic lava flows.	Hydrologic characteristics variable. Fine-grained water-laid deposits have low permeability. Coarser-grained phases and some flow units yield moderate amounts of water. At many places wells yield only a few gallons per minute. At favorable locations wells yield 10 to 50, rarely 100 gpm.	Few available data indicate dissolved solids 300-500 mg/l, water moderately hard to very hard. Sodium adsorption ratio generally less than 2 mg/l.
pT: Consolidated sedimentary, metamorphic, and igneous rocks of pre-Tertiary age.	Graywacke, sandstone, siltstone, mudstone, limestone, tuff, andesitic and felsitic flows and breccia; dioritic and gabbroic intrusive rocks; metamorphic rocks including schist and greenstone.	Rocks generally dense, cemented, and altered. Porosity and permeability generally low to very low. Weathered zone forms shallow reservoir that maintains base flow of streams. Springs and shallow wells yield small supplies for domestic and stock use.	Few data suggest considerable range; dissolved solids from 200 to 500 mg/l. Water moderately hard to very hard; may be saline at some places.

EXPLANATION

Qal

Stream alluvium and basin fill of Pleistocene age.

Coarser deposits yield moderate to large supplies of water. Quantity is related to saturated thickness of these materials.

Dissolved solids generally < 350 mg/l. Water moderately hard to hard. No sodium or boron hazard.

Basaltic and andesitic volcanic rocks of Quaternary and late Tertiary age.

Stores and transmits large amounts of water. Yields moderate to large supplies where 50 to 100 feet are saturated.

Dissolved solids generally <300 mg/l.

Fluvial and lacustrine deposits of Miocene *to early Pleistocene age.*

Generally yields only small supplies, but coarser phases may yield moderate to moderately large supplies.

Dissolved solids probably generally < 500 mg/l. Water moderately hard to hard.

Basalt lava flows and pyroclastics of Miocene and lower Pliocene age.

Thick sequences generally yield moderate to large supplies. One or two flows only small supplies.

Dissolved solids generally < 400 mg/l. SAR generally <2. Generally no flouride, boron hazard.

Silicic volcanic rocks and associated sediments of Tertiary age.

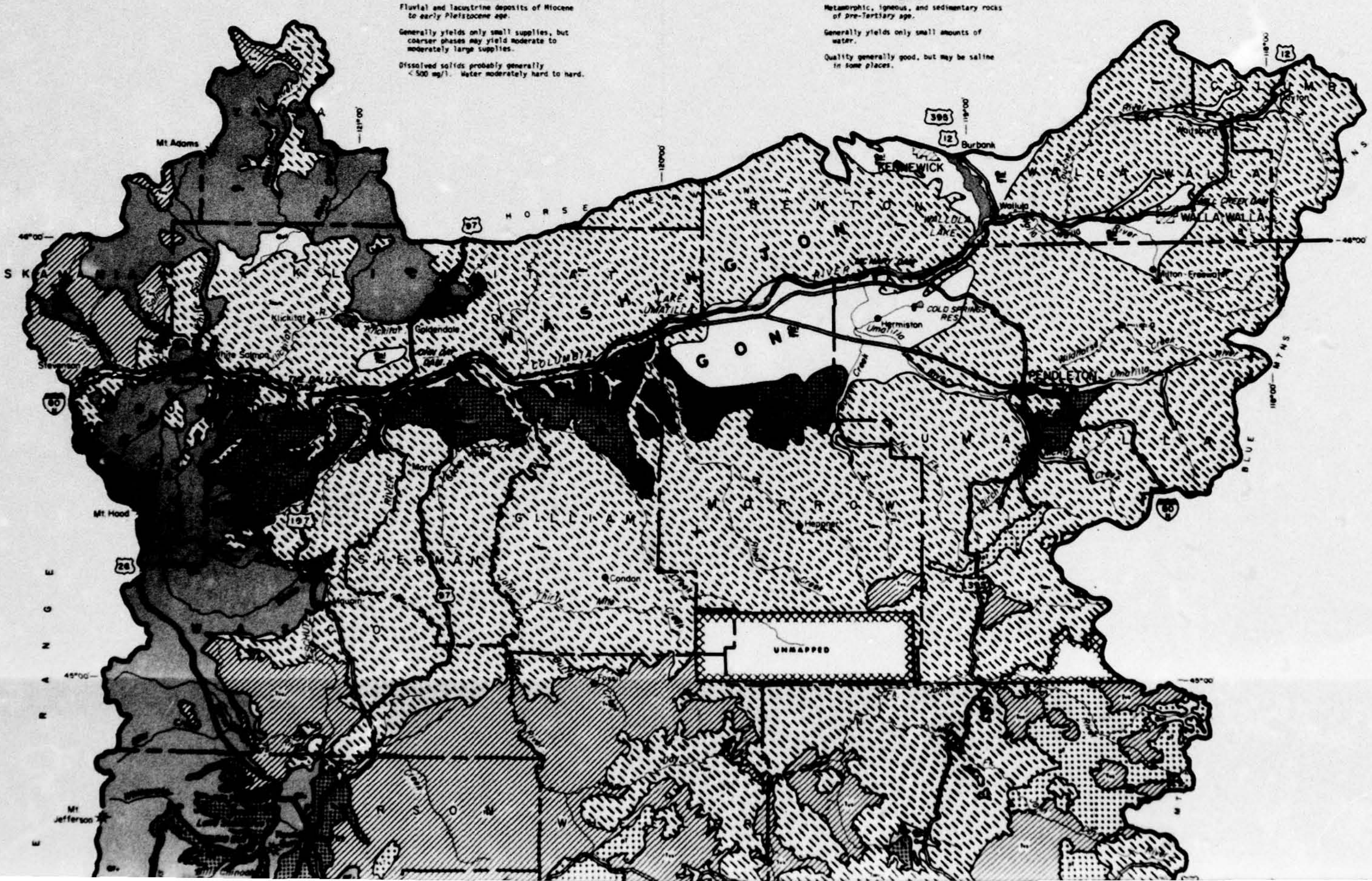
Generally yields only small supplies, occasionally moderate supplies.

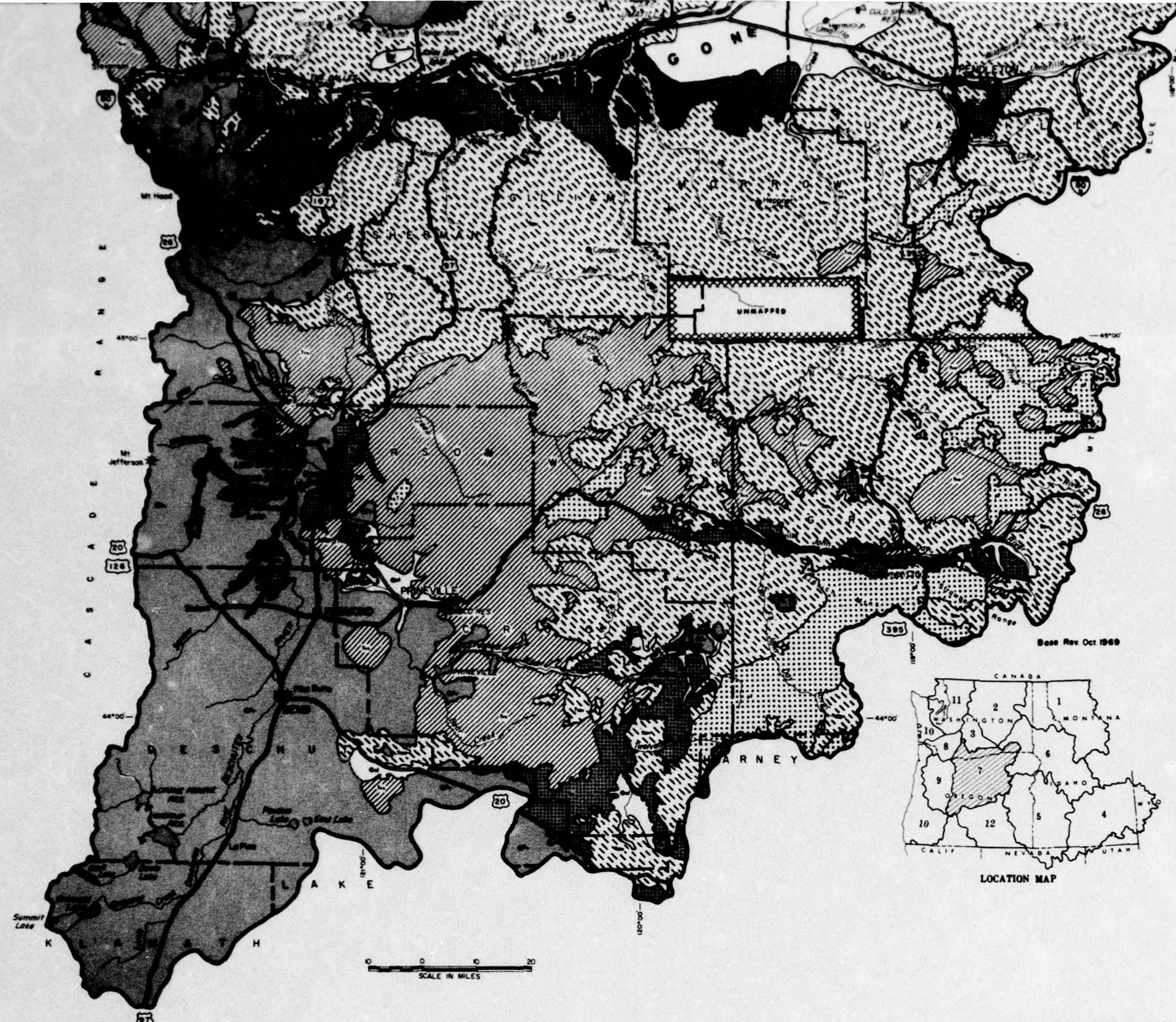
Dissolved solids probably generally 300-500 mg/l. Water moderately hard to very hard.

Metamorphic, igneous, and sedimentary rocks *of pre-Tertiary age.*

Generally yields only small amounts of water.

Quality generally good, but may be saline *in some places.*





COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

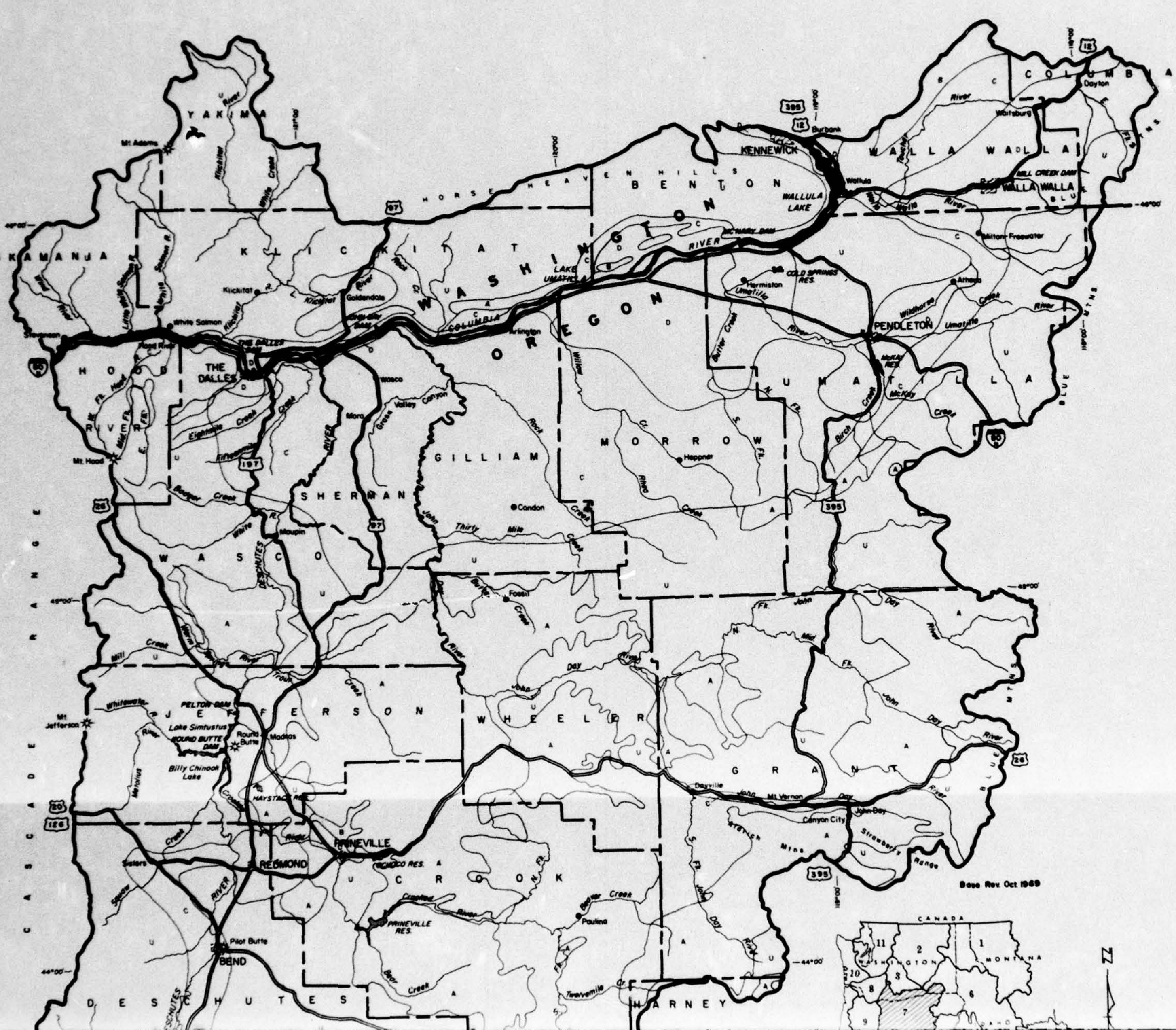
AQUIFER UNITS

MID COLUMBIA SUBREGION 7

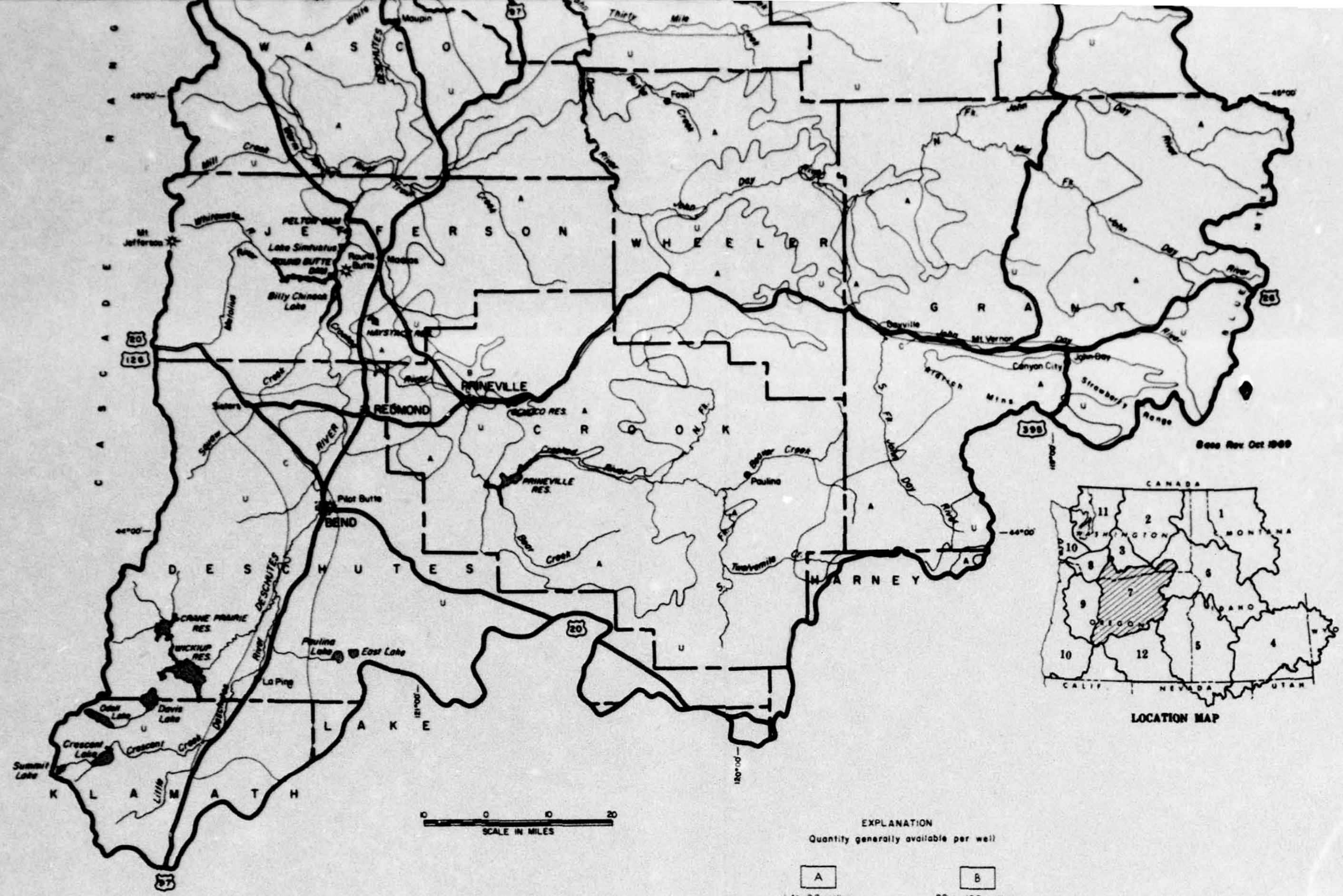
1968

FIGURE 516

2



WASHINGTON
OREGON
YAKIMA
SKAMANIA
KLICKITAT
BENTON
WALLA WALLA
COLUMBIA
HOOD RIVER
WASCO
SHERMAN
GILLIAM
MORROW
UMATILLA
JEFFERSON
WHEELER
GRANT
CROOK
DESCHUTES
HARNEY
KENNEWICK
PENDLETON
THE DALLES
PRINEVILLE
REDMOND
BEND
WALLULA LAKE
LAKE UMATILLA
COLUMBIA RIVER
CASCADE RANGE
HORSE HEAVEN HILLS
Mt Adams
Mt Hood
Mt Jefferson
Base Rev Oct 1969
CANADA
MONTANA



EXPLANATION

Quantity generally available per well

A 1 to 20 gallons per minute	B 20 to 100 gallons per minute
C 100 to 500 gallons per minute	D 500 to 2000 gallons per minute
E More than 2000 gallons per minute	U Yield unknown: See aquifer unit map for information on possible yields

LIMITS OF YIELD

The map shows areas where properly located and properly constructed wells generally are capable of yielding amounts of water within the limits specified in the legend above.

The map does not indicate the total quantity of water that may be safely developed in any given area or aquifer; these determinations generally can be made only on the basis of special investigations.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER

MID COLUMBIA SUBREGION 7

1968

FIGURE 517

Water in Storage

A rough estimate of the quantity of water stored in each aquifer unit, in a specified depth interval below the water table, is given in table 283. A depth interval of 50 feet was used for the pre-Tertiary rocks (pT) and the older volcanic and sedimentary rocks (Tvs) because they underlie mountainous, largely uninhabited areas and the possibility of sufficient ground-water production to lower the water table significantly is remote. A depth interval of 50 feet was used for the alluvial deposits (Qal) because they occur in basins and valleys where recharge opportunity is good and the deposits generally are only 50 to a few hundred feet thick; thus the possibility of any extensive lowering of the water table of more than 50 feet is small. The three other aquifer units underlie extensive upland or plateau areas, and considerable lowering of the water table could occur over extensive areas so a depth interval of 100 feet was used for these units.

The specific yields for five aquifer units, Qal, QTv, Ts, Tmv, and Tvs, were the same as were used in other subregions. For several reasons it was concluded that the zone of saturation within the weathered zone on the pre-Tertiary rocks (pT) is thinner than in some of the other subregions, and a specific yield of 1 percent was used for that unit in Subregion 7. Reasons include the following: the predominantly sedimentary strata weather less deeply than igneous rocks; a fairly low precipitation (20-30 inches) and rugged terrain combine to keep the water table at a relatively lower position in the weathered zone so that the average specific yield of the upper 50 feet of saturated material is less.

Table 283 - Storage, Recharge, and Discharge of Ground Water in Aquifer Units in Subregion 7

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge	
	Sq. Mi.	Acres (1000's)	Specific Yield (percent)	Depth Used (ft)	Water (1000's ac-ft)	Inches Over Area	(1,000's ac-ft)
Qal	1,425	910	20	50	9,000	6	450
QTv	6,500	4,150	5	100	20,800	24	8,300
Ts	2,040	1,370	5	100	6,800	3	340
Tmv	13,465	8,620	1	100	8,600	3	2,150
Tvs	4,400	2,820	1	50	1,400	3	700
pT	1,200	770	1	50	385	3	190
TOTAL (rounded)	29,000				47,000		12,000

The calculated total volume of water stored in the specified depth interval is about 47 million acre-feet (table 283). About 38 million acre-feet are contained in the three major aquifer units.

Natural Recharge and Discharge

Recharge to aquifers is derived chiefly from precipitation within the subregion. However, a very small amount of recharge may be derived by seepage from irrigation-water diversions from the Columbia River. Also, the ground-water divide may not exactly coincide with the western boundary and some ground water may cross beneath the crest of the Cascade Range into Subregion 7.

Recharge to the alluvial deposits is only partly from direct precipitation on the aquifers. A considerable part of the recharge is influent seepage from streams and seepage from irrigation diversions. Most of the area underlain by these deposits is adjacent to major streams including the Columbia, Walla Walla, Umatilla, John Day, and Crooked Rivers, and discharge from aquifers is into these rivers. Most of these areas are arid to semiarid, and recharge from precipitation is low in comparison with more humid areas. Also, extensive areas are not irrigated. For these reasons a relatively low figure of 6 inches over the area was used for average annual recharge.

The Tertiary and Quaternary volcanic rocks (QTv) crop out along the eastern slope of the Cascade Range in the western part of the subregion. Annual precipitation on their area of outcrop ranges from about 10 to 130 inches and may average 40 or 45 inches. There is very little direct-surface runoff from the area underlain by these deposits; most of the precipitation not used by vegetation becomes recharge. Discharge from the aquifer is into such streams as the Deschutes, Metolius, Crooked, Warm Springs, White, and Hood Rivers.

The average annual ground-water contribution to streams draining the Tertiary and Quaternary volcanic rocks (QTv) is equivalent to a range of about 1 to 5 feet of water over their drainage areas. A value of 24 inches was used for average annual recharge to and discharge from the QTv.

The Tertiary volcanic rocks (Tmv) crop out chiefly in uplands and sloping plateaus in the north half of the subregion. Annual precipitation ranges from less than 10 to more than 40 inches, but over most of the area it is less than 25 inches. Average annual precipitation over the area of outcrop is probably between 15 and 20 inches. In much of the area the basalt is overlain by a few to more than 100 feet of Palouse silt. At some places there are

perched aquifers in the silt. The silt is very porous but has low permeability and its most important functions are to supply effluent seepage to streams and to accept and transmit recharge to the basalt. The basalt is recharged by precipitation and snowmelt directly on the area of outcrop, especially where erosion has exposed interflow zones, by downward seepage through the silt, and by influent seepage from streams that are above the water table. For the most part, recharge is probably directly into the interflow zones. Because the central parts of individual flows are dense and nearly impermeable, recharge perpendicular to the flow surface is negligible except where the flow is broken by jointing or other fracturing. Recharge probably is greatly restricted in broad plateaus where basalt flows are parallel to the land surface.

Hydrographs and flow-duration curves for some of the larger streams draining the basalt in semiarid to subhumid areas flanking the Blue Mountains suggest that ground-water discharge from the basalt and overlying Palouse silt to those streams is equivalent to a range of 1 to 10 inches of recharge over the drainage area annually. Recharge to the basalt in the arid parts of the subregion probably is less than 1 inch a year. An average value of 3 inches was used for estimating annual natural recharge to, and discharge from, the basalt.

The pre-Tertiary (pT) and the older volcanic and sedimentary rocks (Tvs) underlie large areas in the Ochoco and Blue Mountains where precipitation generally is 20 to 30 inches a year. Many perennial springs discharge from the fractured and weathered rock and subsoil, and effluent ground water discharges into the valleys throughout the year. In some of the smaller valleys, evapotranspiration by phreatophytes along the valley bottoms may be sufficient to use all the ground water reaching the valleys so that there is no flow in the creeks. Recharge to and discharge from these rocks was given an annual value of 3 inches for each unit.

Hydrographs in figure 518 show water level fluctuations in representative wells. Low-flow characteristics of selected streams are shown in figure 519.

The total annual natural recharge to and discharge from aquifers is about 12 million acre-feet, according to table 283. A considerable part of the ground water that becomes recharge to the alluvium has already been through the ground-water surface-water cycle within the subregion. Some recharge to the basalt may also have been through the cycle. Net recharge to and discharge from aquifers in the subregion probably is 10 or 11 million acre-feet a year.

AD-A036 573 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

UNCLASSIFIED

NL

2 OF 6
AD
A036573

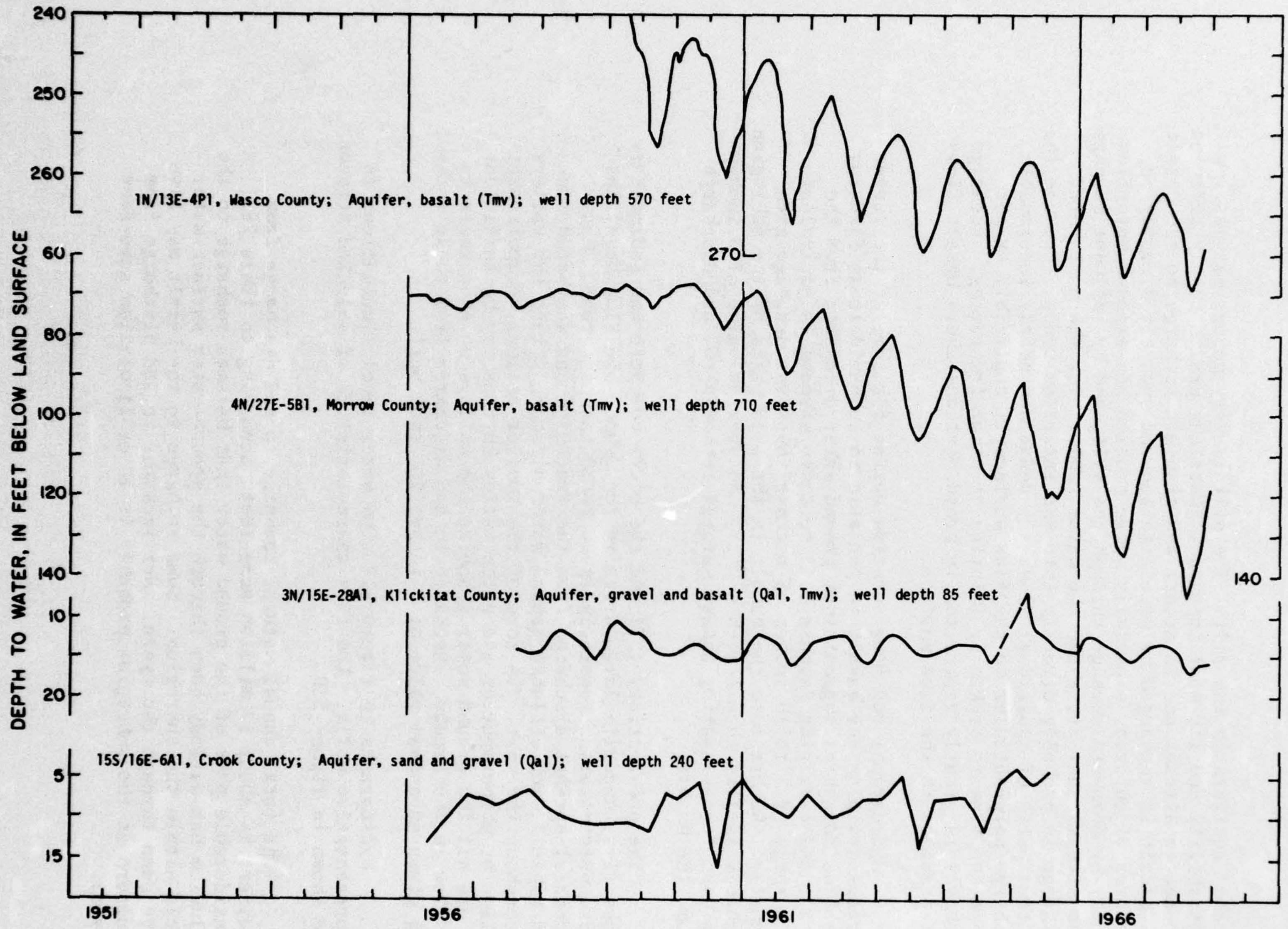


Figure 518 Hydrographs of selected wells in subregion 7

About 90 percent of the ground-water discharge is from the three major aquifers (Qal, QTv, Tmv) and nearly 70 percent of this is from the younger volcanic rocks (QTv). The reason for the latter unit receiving such a large part of the recharge is that not only is it moderately porous and highly permeable, but also it crops out in most of the high rainfall area on the east slope of the Cascade Range.

Annual Ground-Water Withdrawal

Ground-water withdrawal (table 284) amounts to about 300,000 acre-feet a year. A substantial part, perhaps 40,000 acre-feet, is discharged by springs in the alluvial deposits (Qal) in the Walla Walla Basin. Most of the remainder is obtained from wells in the alluvial deposits (Qal) or the Tertiary volcanic rocks (Tmv). The present ground-water withdrawal, 300,000 acre-feet, is about 2.5 percent of the present annual recharge and discharge of ground water in the subregion.

Chemical Quality of Water

Water from the alluvial deposits and the younger volcanic rocks generally has dissolved-solids concentrations of less than 350 mg/l and is moderately hard to hard. Boron and fluoride concentrations are low and the sodium adsorption ratio usually is less than 2. Water from the other rock units (Ts, Tmv, Tvs, and pT) has somewhat greater concentrations of dissolved solids, but usually not exceeding 500 mg/l. The water is moderately hard to very hard. The sodium adsorption ratio may be 5 to 10 in water from some wells in the Tertiary rocks (Tmv) and volcanic and sedimentary rocks (Tvs). Boron commonly is less than 0.3 mg/l, but may be slightly greater from some wells. Fluoride generally is less than 1 mg/l, but ranges up to 5 mg/l from a few wells. Water temperatures commonly range from 45°F. to 60°F. but water from deeper wells in the basalt is warmer. Temperatures commonly range from 55°F. to 75°F. with temperatures increasing with depth.

Present Use and Future Availability

Estimates (projected to 1970) of ground-water withdrawal and consumptive use are given in table 284. Total annual ground-water withdrawal is about 300 thousand acre-feet and consumptive use is about 100 thousand acre-feet. About two-thirds of the withdrawal is for irrigation; nearly all is from the alluvial deposits (Qal) and Tertiary volcanic rocks (Tmv). Much of the irrigation with ground water is in areas underlain by alluvial deposits, and a large part of the water not used consumptively

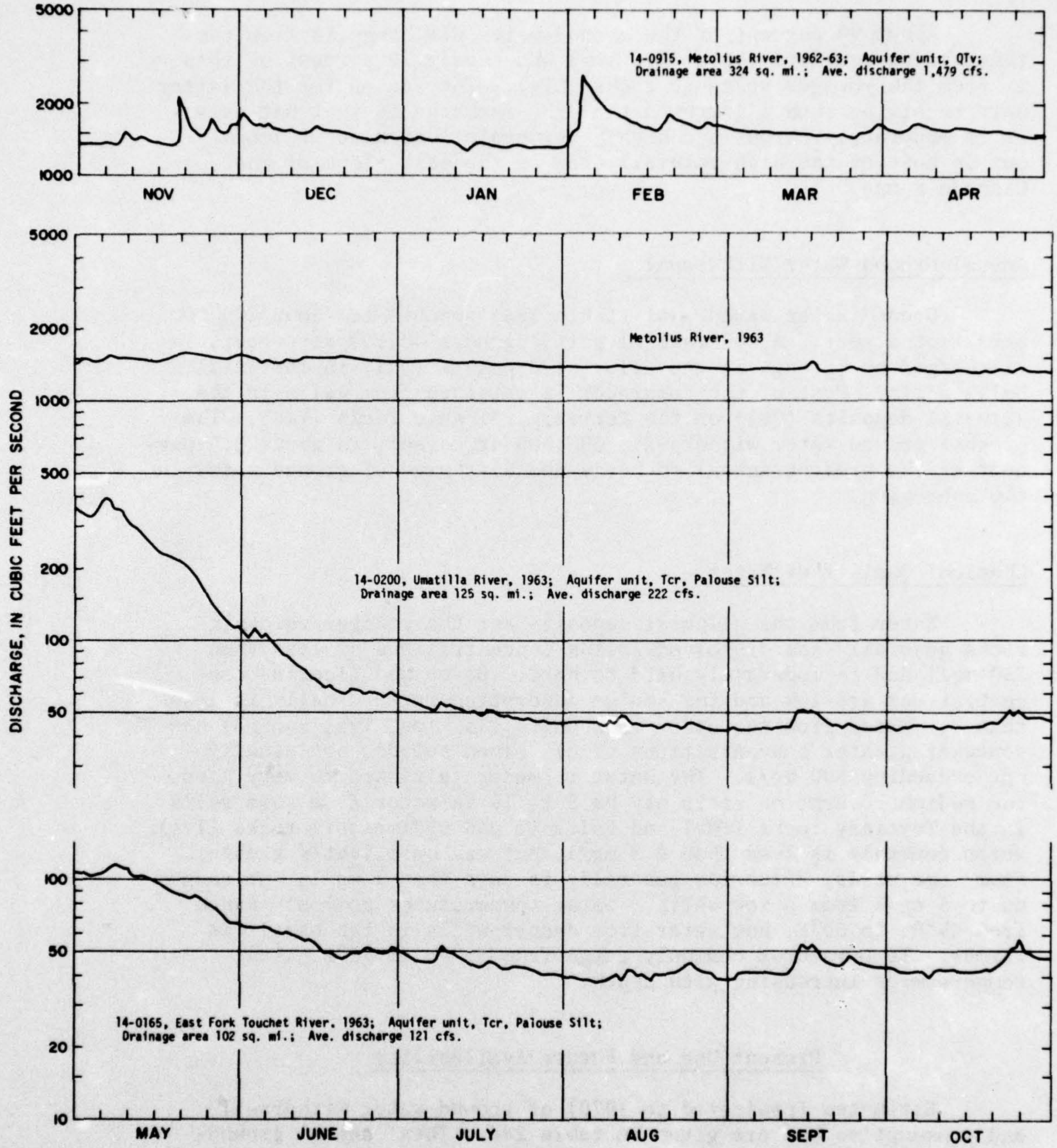


Figure 519 Hydrographs showing low-flow characteristics of selected streams

returns to the aquifers, chiefly the alluvial deposits (Qal). Net ground-water withdrawal, therefore, probably does not exceed 150,000 acre-feet and amounts to about 1 to 1 1/2 percent of the average annual natural recharge to aquifers. However, most of the withdrawal is from aquifers in the arid parts of the subregion, whereas most of the natural recharge and discharge occurs in the humid areas, particularly on the eastern slope of the Cascade Range. For this reason, the available ground water in some areas may not be sufficient to satisfy all future needs.

The recharge, discharge, and movement of ground water in the basalt is greatly complicated by numerous intersecting faults and by other structures. (100) Not only do faults bound many of the major plateau segments, having been a determining factor in the location of some of the larger streams, but they also separate the plateau segments into numerous box-like compartments. Commonly, the permeable interflow zones are interrupted by the faults through which the water can percolate only slowly. Thus, the water table may slope only slightly within a compartment, but decline hundreds of feet as the water moves through the fault barrier into the next compartment downgradient. Because the land surface may slope more steeply than the water table within a particular compartment, a reach of the stream above the fault barrier may lose water by influent seepage in the upgradient part of the compartment but gain effluent seepage in the downgradient part. Recharge to the basalt thus may be localized by faults and other structures and the movement of ground water restricted by the structures. In arid parts of the subregion, where recharge is limited, pumpage from wells may cause large drawdowns over a limited area without affecting water levels across a structural barrier a few miles away. Static water levels also are greatly influenced by faults and other structures; the water table in wells a short distance apart may differ by several hundred feet because the wells are on opposite sides of a fault. Many wells in the basalt on the north flank of the Blue Mountains, from Pendleton through Heppner to Condon, flow or have static levels near land surface; presumably the water is held at high levels by structural controls. In contrast, down the regional dip to the north and at much lower altitudes, the static water level in many wells is several hundred feet below land surface.

One area, The Dalles Critical Ground-Water Area, has been declared a critical area by the Oregon State Engineer because of lowering of the water table. The Ordnance and Butter Creek Critical Ground-Water Areas in Morrow and Umatilla Counties probably will be declared. Also, lowering of the water table in Walla Walla Valley is presently being investigated. These areas are examples of the effects of a concentration of withdrawal in areas where recharge from precipitation is small and structural barriers limit lateral inflow.

Table 284 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 7, 1970

	Ac-ft per year; all quantities in thousands		
	Oregon	Washington	Total
Irrigation			
Acres irrigated	30.0	18.0	48.0
Withdrawal	120.0	70.0	190.0
Consumptive use	60.0	35.0	95.0
Industrial 1/			
Withdrawal	56.0	5.0	61.0
Consumptive use 2/	2.8	.2	.3
Public Supplies			
Persons served	58.0	24.0	82.0
Withdrawal	19.0	9.4	28.0
Consumptive use 3/	3.8	1.9	5.7
Rural-Domestic			
Persons served	40.0	30.0	70.0
Withdrawal 4/	4.5	3.4	7.9
Consumptive use 5/	2.2	1.7	3.9
Stock			
Withdrawal and consumptive use 6/	1.3	.9	2.2
TOTAL WITHDRAWAL (rounded)			300.0
TOTAL CONSUMPTIVE USE (rounded)			100.0

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

Artificial Recharge

Studies of the feasibility of artificial recharge of the basalt of the Columbia River Group (Tmv) have been made at Walla Walla (122) and at The Dalles (33). Both studies concluded that artificial recharge of the basalt was feasible. At Walla Walla, beginning in 1957, surplus water from Mill Creek has been used to recharge the basalt during a 3- to 4-month period each winter. The water is injected into the aquifer through one of the City's production wells that doubles as a recharge well. About 300 to 350 acre-feet of water is injected annually. So far as is known, this is the only artificial recharge being done in Subregion 7.

The alluvial deposits (Qal) generally are suitable for recharge operations by water spreading, and the extensive deposits in the Hermiston-Boardman area might be benefited by artificial recharge. The Tertiary and Quaternary volcanic rocks (QTv) also are suitable for this purpose; however, in much of the area they already receive a large amount of natural recharge. In areas where precipitation and natural recharge are much less, as in the vicinity of, and east of Bend, it is not apparent how artificial recharge would be of benefit. For the most part, the water table is many hundred feet below land surface, and, because of the high permeability of the aquifers, artificial recharge would generally raise the water table very little. At the present time pumpage from that aquifer unit is small. Detailed studies would be required to determine whether there are areas that could be benefited by artificial recharge.

Water Rights

Oregon

In the Oregon part of the subregion, consisting of the Deschutes, Hood, John Day, and Umatilla Basins, primary water rights for 956 wells are on file with the State Engineer's Office as of March 1967. Primary rights allow withdrawal of 296,883 acre-feet a year, of which 114,509 acre-feet is for irrigation of 36,544 acres. The maximum rate of withdrawal is 670 cfs (301,000 gpm) during the irrigation season. Data on supplemental water rights are not available. Ground-water rights are summarized, by major use category, in table 285.

Washington

In the part of the subregion lying within the State of Washington, essentially Water Resource Inventory Areas 29 through 32 (figure 426), a total of 849 active ground-water right

appropriation and declaration records, in permit and certificate stages, were on file with the Department of Water Resources as of September 30, 1966. Prime rights in this area allow summer-period consumptive withdrawals totaling 241,474 gpm (538 cfs). A total of 1,650 gpm has been appropriated under supplemental rights.

Table 285 - Summary of Ground-Water Rights, Oregon Part of Subregion 7, 1967

Basin No.	Basin Name	Number of Wells	Domestic (ac-ft)	Municipal (ac-ft)	Industrial (ac-ft)	Irrigation (acres)	Irrigation (ac-ft)	Other (ac-ft)	Total (ac-ft)
4	Hood	113	0	18,843	11,787	4,224	12,672	0	43,302
5	Deschutes	105	0	8,245	21,171	4,216	12,648	72	42,136
6	John Day	28	0	4,485	14	285	854	0	5,353
7	Umatilla	710	0	77,388	40,100	27,819	88,335	269	206,092
TOTAL		956	0	108,961	73,072	36,544	114,509	341	296,883

Prime water-right quantities for the more important use categories and total actual ground-water right quantities are listed in table 286, according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 286 - Summary of Ground-Water Rights, Washington Part of Subregion 7, 1966

Basin No.1/	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total2/
				(Gallons per Minute)				
29	Wind White Salmon	-	217	740	1,200	2,000	-	2,877
30	Klickitat	-	6,685	7,237	740	-	380	10,282
31	Rock-Glade Creek	-	12,174	7,748	54	-	2,603	14,795
32	Walla Walla	21,925	173,434	56,899	19,538	-	22,602	213,520
TOTAL		21,925	192,510	72,624	21,532	2,000	25,585	241,474

1/ Water Resource Inventory Area number as shown in figure 426.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

Because of the great differences in precipitation and in porosities and permeabilities of aquifers, there are wide differences in the relations between surface and ground water.

On the east slope of the Cascade Range, annual precipitation ranges from about 60 to 100 inches at the crest to less than 20 inches at the foot of the mountains. Practically the entire area is underlain by porous Quaternary and Tertiary volcanic rocks (QTv)

and most of the precipitation sinks into this aquifer unit. The major trunk stream, the Deschutes River and its tributaries, is largely fed by ground-water effluent. The Metolius River, with an average discharge of 1,483 cfs (through 1966), at the gage near Grandview, averages about 97 percent ground-water effluent. The annual ground-water component of discharge is equivalent to about 60 inches over the drainage basin--considerably more than average precipitation on the basin. This indicates some interbasin diversion of ground water into the drainage, possibly from the west side of the Cascade Range.

Farther east, streams heading in the Blue Mountains drain terrain underlain by basalt, older volcanic and sedimentary rocks, and pre-Tertiary rocks (Tmv, Tvs, and pT). These aquifers receive considerable recharge from 20 to 40 inches of precipitation, and most streams receive effluent seepage throughout the year. To the north, precipitation is only 10 to 20 inches. The basalt (Tmv) slopes gently northward off the Blue Mountains and small streams originating on the sloping upland are intermittent and ephemeral, gaining water from direct precipitation and permanent or temporary perched water tables, and losing water to the regional water table. At places, some of the streams may alternately gain or lose water as they cross geologic structures. Only the major trunk streams are incised deeply enough to intersect the regional water table and receive perennial inflow of ground water. The Columbia River is the base level for all water; both surface and ground water drain into it.

S U B R E G I O N 8, L O W E R C O L U M B I A

HYDROLOGIC FRAMEWORK

The Lower Columbia Subregion lies within the State of Washington, except for a small section in Oregon downstream from the Willamette River and bordering the Columbia River. The area, encompassing essentially the Cowlitz and Lewis River Basins, is bounded on the north by the low divide of the Chehalis River Basin, on the east by the Cascade Range, on the south by the Columbia River and the Clatskanie River Basin Divide, and on the west by the low Coast Range. The subregion covers 5,103 square miles, of which 115 square miles are fresh water and 4,988 are land, the total amounting to about 2 percent of the regional area. Elevations vary from 50 to 500 feet above sea level in the lower valleys, increasing to 2,000 feet along the eastern slope of the Coast Range and 4,000 to 8,000 feet along the western slope of the Cascades.

Figure 2 shows the major physiographic features. Located between the Coast and Cascade Ranges, the subregion is characterized by a structural downwarping of the rock strata west of the Cascade Range that has been severed by the Columbia River. Tertiary rocks and associated volcanics rise in a series of low folds to form the Coast Range. Tertiary rocks, consisting of marine shales and sandstones, great thicknesses of basaltic lavas, and lesser amounts of volcanic tuffs and tuff breccias form the floor of the subregion from the Columbia River northward. These rocks are mantled with alluvial materials through which rise occasional hills of more resistant underlying sedimentary and volcanic rocks. In addition, flat-lying beds of gravels, sands, and clays of Quaternary age are present on terraces along many of the valleys in this area. The Lewis, Cowlitz, and tributary rivers rise in the Cascade Range. These streams occupy superimposed positions in old, broad, filled, and glaciated ancestral valleys. These rivers have generally cut down below the floor of the parent valleys and now flow through rather narrow canyons cut into tertiary lavas, pyroclastics, and sediments.

Streams originating in this subregion averaged about 67 inches of runoff per year, or 24,970 cfs, during the base period 1929-58. The maximum was about 1 1/2 times and the minimum a little over 1/2 the average.

The two principal streams in this area are the Cowlitz and Lewis Rivers, both of which rise in the Cascade Range and flow southwesterly to their confluences with the Columbia River.

The Cowlitz River is nearly always milky in appearance because of the silt associated with the glaciers of Mount Rainier and Mount St. Helens. The Lewis River is less turbid because it drains the southeast side of St. Helens and only part of the west side of Mount Adams. The glaciers tend to regulate streamflow by accumulating and storing precipitation during cold, wet years and releasing more than average amounts of water during hot, dry years. Stream gradients for the Lewis River range from about 4 percent in the upper reaches to a low of 1/4 percent at its mouth. The Lewis River contributes about 80 inches of runoff per year. The Cowlitz River gradients range from about 5 percent in the upper reaches to about 1/5 percent in the valley areas. The river contributes about 54 inches of runoff per year.

The region's major stream, the Columbia River, forms the southern boundary of most of the subregion and receives all of its runoff. Smaller streams of importance include the Wind, Washougal, Coweeman, and Toutle Rivers in Washington and the Clatskanie River in Oregon.

This subregion is heavily forested, Douglas-fir being the principal growth along with some Western Hemlock. Farmlands occupy the Columbia and Cowlitz River Valleys, with most of this area dryfarmed. The irrigated sections are along a 20-mile strip of the Cowlitz River near the mouth of the Lewis River and scattered areas near Vancouver. Large areas of irrigable land surround Vancouver in the extreme south of the subregion.

Vancouver, the largest city, had a population of 32,460 in 1960.

CLIMATE

Terrain, prevailing direction of the wind, and distance from the ocean have an influence on the climate. The Coast Range protects this area from the more intense winter storms moving inland from over the Pacific, and the Cascades shield it from the higher summer and lower winter temperatures observed in eastern Washington. The narrow Columbia River Gorge through the Cascades permits some exchange of air between eastern and western sections of the State. The direction and speed of the air movement through the gorge are determined primarily by the pressure gradient between the eastern and western slopes of the mountains. In summer, the flow is usually from west to east; however, due to the unequal heating on the two sides of the Cascades, there is some diurnal variation in the direction. In winter, the prevailing flow is from east to west as colder air drains out of the inland basin of eastern Washington. Winds in the gorge may reach gale force as the more intense storms approach the Washington coast. Most of

the air masses crossing this subregion have their source over the ocean, and this maritime air has a moderating influence in both winter and summer. Occasionally, dry air from the interior of the continent reaches western Washington.

Precipitation

There is a well-defined dry season in summer and a rainy season in winter. In summer, the prevailing flow of air is from the west or northwest. Cool air from over the north Pacific becomes warmer and drier as it moves inland. This circulation results in a dry season beginning in late spring and reaching a peak in midsummer. In late fall and winter, the prevailing flow of air is from the southwest. This maritime air is moist and near the surface temperature of the ocean. Orographic lifting and cooling of the air as it moves inland results in a rainy season beginning in the fall, reaching a peak in the winter, then gradually decreasing in spring. Approximately 50 percent of the annual precipitation falls in the four months, October through January, and 75 percent in the period October through March. Total rainfall for the two months, July and August, is less than 5 percent of the annual. During the wet season, rainfall is usually of light or moderate intensity and continuous rather than as heavy showers. From west to east, annual precipitation decreases along the leeward slope of the Coast Range from 90 inches or more at the crest to 50 inches in the lower river valleys, then increases to 100 inches or more in the wettest areas along the windward slope of the Cascades. Measurable rainfall is recorded on 3 to 7 days each month in summer; 8 to 15 days in spring and fall; and 15 to 25 days in winter. Table 287 and figure 520 show precipitation data and location of stations.

Table 287. Average Monthly and Annual Precipitation (inches), Lower Columbia Subregion, 1931-60

Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Longview	12	5.81	4.87	4.85	2.72	2.30	2.14	.75	1.26	2.01	4.40	6.43	7.56	45.10
Kid Valley 1/	690	7.01	6.88	6.40	4.57	3.30	2.85	1.00	1.59	2.38	5.62	7.47	8.56	57.63
Wind River	1,150	16.05	12.53	11.49	6.26	3.74	2.54	1.01	1.12	2.96	8.74	14.68	18.39	99.51
Bonneville Dam 1/	85	10.87	9.22	8.28	4.85	3.73	2.71	.82	1.10	2.77	7.52	11.21	12.40	75.48
Battle Ground 1/	295	7.12	5.23	5.41	3.30	3.07	2.60	.63	1.03	2.35	5.34	7.60	8.25	51.93
Kalama 5 ENE	900	9.08	6.99	7.58	4.35	3.25	2.73	.93	1.51	2.54	5.94	8.59	10.48	63.97

1/ Period is longer or shorter than the 30-year normal.

Figure 520 is an isohyetal map of mean annual precipitation prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors.

In the lower elevations, snowfall is light and seldom remains on the ground longer than two weeks or reaches depths in excess of 10 to 15 inches. Snowfall increases in the mountains with the snowline in midwinter at 1,500 to 2,000 feet above sea level. In the higher mountains, snow can be expected in October and to remain on the ground until June or July. Above 8,000 feet, it is not unusual for snow to fall in midsummer. In elevations between 2,500 and 4,000 feet, winter season snowfall is from 150 to 300 inches; and above 5,000 feet, 300 to 500 inches.

Maximum snow depths during severe winters are 20 to 30 inches in the lower elevations, 50 to 75 inches at 2,000 feet, 150 inches to 200 inches at 3,000 feet and 200 to 300 inches above 5,000 feet. The terrain and exposure of an area have decided influences on the accumulation of snow. Density of the snow pack increases from approximately 25 percent water equivalent in early winter to 45 percent in April.

Temperature

During the summer months, afternoon temperatures in the lower elevations range from 70° to 80°F., reaching 90°F. on 5 to 15 days and 100°F. in one out of four summers. Minimum temperatures vary from 45° to 55°F. In the mountains, afternoon temperatures are in the 60's or lower 70's in elevations from 4,000 to 5,000 feet, and nighttime readings are in the 40's. In the higher mountains, below-freezing temperatures are not unusual in midsummer. The highest temperatures and lowest relative humidities are recorded when air from east of the Cascades reaches this area.

During the winter, maximum temperatures in the lower valleys range from 35° to 45° F., and minimums from 25° to 35°F. In the mountains, afternoon temperatures are near 30°F. and minimums 20°F. In general, temperatures can be expected to decrease 3° to 4°F. with each 1,000-foot increase in elevation. Below-freezing temperatures are recorded on 50 to 90 nights in the lower valleys and on most nights between mid-October and mid-April in the mountains. During occasional outbreaks of cold air from the interior of the continent, minimum temperatures drop to near or slightly below zero. The cold outbreaks are usually of short duration. Table 288 and figure 520 show temperature data and location of weather stations.

In the agricultural areas, the growing season varies from approximately 140 days in the colder valleys to 180 days in the warmest. Average date of the last 32°F. temperature in the spring is mid-April in the warmer areas and mid-May in the colder localities. In fall, the average date of the first 32°F. temperature varies from the first to the last of October. However, at Vancouver the growing season has a duration of 234 days. The

average date of the last 32 °F. temperature in the spring is March 25, and in the fall the average date for the first 32°F. temperature is November 15.

Table 288 - Average and Extreme Temperatures (°F), Lower Columbia Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Longview	Av. Max.	44.2	49.5	54.6	61.5	67.6	72.1	77.7	77.3	72.8	63.2	52.4	46.8	61.6
(35)	Av. Min.	31.6	33.4	35.5	38.9	43.0	47.7	50.3	50.6	48.2	43.0	36.8	34.2	41.1
	Mean	38.1	41.2	44.6	50.0	55.3	59.7	64.1	64.0	60.7	53.1	44.5	40.7	51.3
	Highest	65	68	81	89	97	100	105	103	104	88	77	66	105
	Lowest	-20	2	19	24	27	31	32	35	29	24	8	4	-20
Kid Valley 1/	Av. Max.	42.2	46.4	51.1	59.5	66.7	69.6	76.9	75.2	70.0	58.8	49.3	44.6	59.2
(18)	Av. Min.	29.4	32.0	33.0	36.9	41.7	46.2	48.2	48.7	45.3	40.5	35.0	32.7	39.1
	Mean	35.8	39.2	42.0	48.2	54.2	57.9	62.6	62.0	57.7	49.6	42.1	38.7	49.2
	Highest	63	65	74	85	92	98	103	99	90	77	65	62	103
	Lowest	-9	-3	13	25	27	34	36	36	32	23	4	15	-9
Wind River	Av. Max.	38.5	43.6	50.7	59.4	66.9	72.6	80.5	79.6	72.7	61.2	48.1	40.7	59.5
(47)	Av. Min.	25.3	27.6	30.3	33.9	39.4	44.7	47.3	46.8	42.7	37.5	32.1	28.8	36.4
	Mean	32.0	35.5	40.2	46.6	53.2	58.1	63.5	62.5	58.0	49.4	39.7	35.0	47.8
	Highest	64	67	82	92	96	100	107	103	100	89	70	63	107
	Lowest	-12	-18	3	20	20	29	33	32	25	13	-1	-13	-18
Battle Ground 1/	Av. Max.	44.7	50.3	54.5	61.2	68.2	71.8	79.5	78.9	75.8	64.4	53.6	47.6	62.5
(16)	Av. Min.	29.9	33.0	33.9	37.3	41.6	46.0	47.3	47.8	44.4	40.4	35.1	33.2	39.2
	Mean	37.4	41.7	44.2	49.3	54.9	59.0	63.3	63.3	59.8	52.4	44.4	40.5	50.9
	Highest	63	68	80	91	96	100	107	103	105	93	72	64	107
	Lowest	-11	-9	16	25	26	34	36	35	26	22	4	15	-11

1/ Period is longer or shorter than the 30-year normal.
Note: The mean temperature is for the normal period 1931-60; other data are for the period of record through 1960. Numbers under station names denote full years of record for all data.

Wind

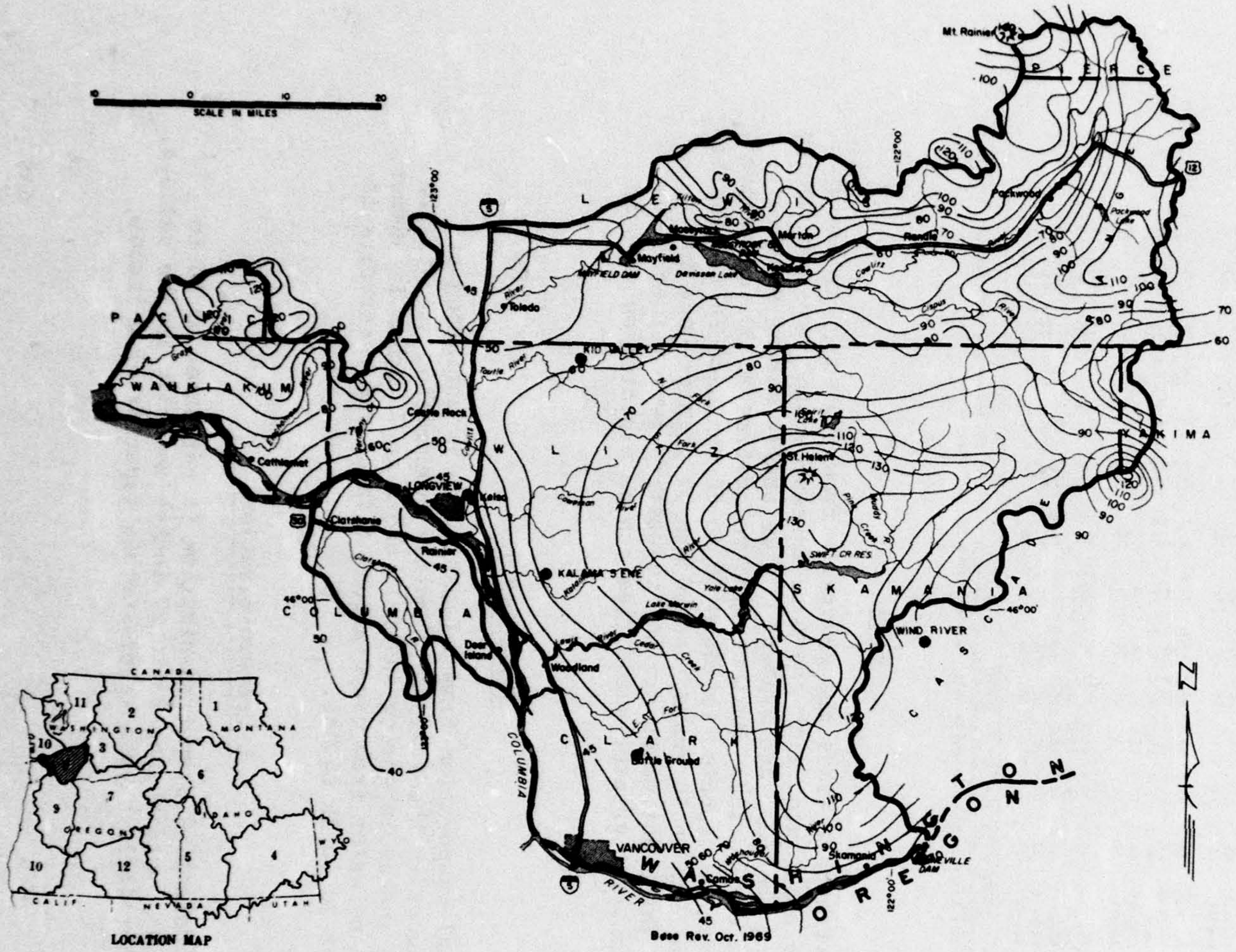
The strongest winds are generally from the south or southwest and are associated with the more intense weather systems moving inland during the fall and winter. Occasionally strong southeasterly winds are reported. Maximum wind velocities at 30 feet above the ground can be expected to reach 50 to 60 mph once in two years; 75 to 85 mph once in 50 years; and 90 mph or greater once in 100 years. These estimates are for velocities over rather level terrain. Somewhat greater velocities can be expected on exposed ridges.

Evaporation

Annual evaporation from a Class A pan is estimated at 30 to 35 inches in the valleys. Monthly evaporation amounts are from 2 to 3 inches in spring and fall and 5 to 7 inches in summer. Annual loss of water from evaporation of lakes and reservoirs is estimated at 20 to 25 inches.

Evapotranspiration

The potential evapotranspiration is estimated at 16 to 18 inches in mountains and 23 to 27 inches annually in the valleys.



EXPLANATION

—70— MEAN ANNUAL PRECIPITATION

● PRECIPITATION STATION

NOTES:

1. ISOHYETAL ANALYSIS PREPARED BY THE U.S. WEATHER BUREAU RIVER FORECAST CENTER, PORTLAND, OREGON, USING ADJUSTED CLIMATOLOGICAL DATA (1930-1957) AND VALUES DERIVED BY CORRELATION WITH PHYSIOGRAPHIC FACTORS.
2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

LOWER COLUMBIA SUBREGION 8

1968

FIGURE 520

estimates have been made of the actual evapotranspiration which occurs with normal precipitation and temperatures. These estimates indicate actual evapotranspiration on an annual basis ranges from 15 to 20 inches.

Storms

Thunderstorms are reported on one to three days each month from March through October and have occurred in all months. The average number of thunderstorms each year is five to eight in the valleys and 10 to 15 in the mountains.

Rather severe ice storms, or "silver thaws" as they are frequently called, occur in a narrow area westward from the Columbia River Gorge to the vicinity of Vancouver. These ice storms are the result of rain falling into cold air as it moves westward through the gorge and spreads over the lowlands along the river. Infrequent hail or sleet storms occur but seldom reach destructive proportions.

Nearly all of the widespread winter precipitation in the subregion is produced either by a family of mature occlusions or by a quasi-stationary front with active minor waves. These storms may extend many hundreds of miles to the north or south. Tropical cyclones are extremely rare.

Humidity

Relative humidity during the early morning hours may be near 100 percent any time of the year. The 4:00 a.m. average on a year-round basis is between 85 percent and 90 percent. During the warmer part of the day, however, there is a considerable variation from winter to summer. The 4:00 p.m. average ranges from 80 percent in December to about 30 percent in July, occasionally falling to less than 20 percent.

Sunshine

The number of clear or only partly cloudy days ranges from four to seven in winter, 10 to 15 in spring and fall, and 20 or more in summer. The amount of sunshine received each month is approximately 20 percent of the amount possible in winter, 40 to 50 percent in spring and fall, and 65 percent or more in summer.

SURFACE WATER

The rivers of the Lower Columbia subregion are well used, have a large supply of water per square mile, and have a generally good quality. The runoff is primarily from winter rainfall with combinations of rain and melting snow in the spring. Flood flows are regulated considerably by reservoirs, two on the Cowlitz and three on the Lewis River.

Water is used for power generation at the Lake Merwin, Yale, and Swift Creek reservoirs on the Lewis River, at the Mayfield, Mossyrock reservoirs on the Cowlitz, and at Packwood Lake on Lake Creek.

Irrigation development has been slow and by private initiative. The need for widespread development has not been expressed by local interest, due to the type of crops grown and extensive areas of uncleared land.

Quantity

Average annual runoff of streams originating in the subregion totals 24,970 cfs (18.1 million acre-feet annually). This averages 4.9 cfs per square mile, the highest rate of any subregion in the Columbia-North Pacific Region.

Present Utilization

About 2.4 percent of the originating mean discharge was withdrawn for consumptive uses in 1965, but only about 0.1 percent was actually consumed. About 5 percent of the water withdrawn for consuming uses (588 cfs) is for municipal supplies (25 cfs domestic and 2 cfs industrial). The largest user is self-supplied industry (512 cfs). Irrigation (43 cfs) is a slightly larger user than municipal supplies, but it is the major consumer, 20 cfs of the total of 31 cfs consumed. Thermal power generation is minimal but will be a leading product when the nuclear plant planned for the lower Columbia River is completed. A small quantity of water is used to generate hydroelectric power. Navigation of all forms takes place in the Columbia River. Recreation is a major industry, particularly in the Columbia River, but also on the power reservoirs and rivers. Fish and wildlife are in abundance and attract sportsmen and commercial enterprises. Water is generally abundant for the transport and dilution of waste except in the Columbia River where bacterial levels and slime growths constitute a problem.

Stream Management

Competition for water among the various users necessitates efficient stream management. Storage and release, diversions, conservation, legal constraints, etc., all are parts of the water management system.

Impoundments Reservoirs having a total capacity of 5,000 acre-feet or more are listed in table 289. Mossyrock Dam on the Cowlitz River forms the largest impoundment, Davisson Lake. Swift Creek Reservoir is the largest of the three reservoirs on the Lewis River. The table includes five reservoirs, two on the Cowlitz and three on the Lewis. Although the primary functions of these impoundments are for power or water supply, considerable flood control is provided and all of the reservoirs are used for recreation.

Table 289 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More, Subregion 8

Name	Stream	Total Storage (ac-ft)	Active Storage (ac-ft)	Surface Area (acres)	Purpose 1/
Lake Merwin	Lewis R.	421,600	246,000	3,920	P
Mayfield	Cowlitz R.	127,000	21,380	2,250	P
Davisson Lake	Cowlitz R.	1,586,000	1,297,000	-	P
Swift No. 1	Lewis R.	756,000	447,000	4,620	P
Yale	Lewis R.	401,780	189,530	3,780	MP

1/ M-municipal, P-power

The impoundments have variable short-term effects on river discharge. The changes in discharge due to power loads are abrupt, and on weekends, when less power is required, flows may be low. Municipal water is supplied during the summer principally to satisfy lawn-watering and air-conditioning needs. On the other hand, normal reservoir levels are retained as long as possible during the summer and early fall to accommodate the recreationists.

Diversions Diversions for irrigation in this subregion are minor. However, there is appreciable sprinkler irrigation from wells. Other diversions are made for municipal, industrial, and drainage uses.

Channel Modification Major dredging and construction of pile dikes are performed in the Columbia River for construction and maintenance of the navigation channel. Some levee systems for flood protection have been constructed on the Cowlitz and Lewis Rivers near affected towns.

Forecasting Forecasting is used in flood control operations of reservoirs, flood warning, and to provide a maximum of stored water for power generation, municipal use, and irrigation, consistent with assured refill.

Forecasts of seasonal quantities of water available for storage are made using snow survey data, precipitation data, data on antecedent conditions, and other parameters. The information is processed by digital computer and updated each month as new data are obtained.

Constraints There are no interstate compacts or international treaties that are concerned with runoff in the Lower Columbia Subregion. The 1961 treaty with Canada concerning the Columbia River will have only indirect effects on the subregion. However, there are restrictions involved in the operation of subregional reservoirs.

The first consideration is to maintain, as nearly as possible, sufficient minimum flow to satisfy prior water rights. The second requirement is the flow of water advocated by the Fish and Wildlife Service and the Washington State fish and game authorities as adequate for the normal resident fish population and the anadromous fish runs.

Water Rights

In that part of the Lower Columbia Subregion located in the State of Washington, essentially Water Resource Inventory Areas 25 through 28 (figure 521), a total of 1,187 active surface-water appropriation records, in permit and certificate stages, were on file with the Department of Water Resources on April 30, 1967. Prime rights in this area allow summer period diversions totaling 44,100.72 cfs of which consumptive diversions amount to 470.80 cfs, partially consumptive diversions are allowed for 920.85 cfs and nonconsumptive diversions account for 42,709.07 cfs. A total of 53.35 cfs has been appropriated under supplemental rights.

Reservoir storage rights on record with the Department of Water Resources permit a total of 2,898,741 acre-feet to be retained in storage annually in the Lower Columbia Subregion.

Prime water right quantities for the more important use categories and total actual surface-water right quantities are listed in table 290 according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

Figure 521. Water resource inventory areas defined by the State of Washington Department of Water Resources.

Table 290 - Surface Water Rights in the Lower Columbia Subregion, 1967

Basin No. 1/	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total 2/	Reservoir Storage Rights
		(Cubic Feet per Second)							(Acre-Feet)
Appropriative Rights									
25	Cathlamet Area	3.10	17.12	3.87	195.00	125.18	0.22	344.49	-
26	Cowlitz	164.80	54.45	11.22	36.23	202.88	0.92	33313.29 3/	1717882 7/
27	Kalama-Lewis	2.00	49.39	23.56	26.62 4/	63.56	0.59	9846.99 5/	1180693 8/
28	Vancouver Area	4.50	45.93	24.12	122.23	112.51	0.44	595.95 6/	166
TOTAL		174.40	166.89	62.77	380.08	504.13	2.17	44100.72	2898741

1/ Water Resource Inventory Area Number as shown in figure 521.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.
3/ Includes 32,852 cfs for hydroelectric power generation.
4/ Includes 20.07 cfs for heat exchange.
5/ Includes 9675.00 cfs for hydroelectric power generation.
6/ Includes 312.20 cfs for hydroelectric power generation.
7/ Includes 127,000 acre-feet in Lake Mayfield and 1,586,300 acre-feet in Mossyrock pool.
8/ Includes 220,000 acre-feet in Lake Merwin, 220,000 acre-feet in Yale Lake, and 740,000 acre-feet in Swift Reservoir.

Discharge

A typical Subregion 8 stream, Lewis River at Ariel, Washington, shows a base period (1929-58) mean discharge equal to 99 percent of its long-term mean (42 years, 1924-1965). Weather records show that precipitation in Castle Rock, Washington, during the base period was 100 percent of the long-term mean (41 years, 1925-65). Thus, the selected base period provides reasonably average data for statistical analysis.

Measurement Facilities Measurement facilities comprise primarily the gaging stations where the measurements are made. Table 291 summarizes pertinent streamflow data for the eight sites selected for detailed study. Figure 523 shows the locations of the selected sites, with Geological Survey identification numbers.

Table 291 - Streamflow Summary for Selected Sites, Subregion 8

Stream	Station	Station Number	Gage Datum	Drainage Area (sq. mi.)	Period of Record	Annual Flow[1/] Mean (cfs)	Annual Flow[1/] Max. (cfs)	Annual Flow[1/] Min. (cfs)	Momentary Flow[2/] Max. (cfs)	Momentary Flow[2/] Min. (cfs)
Lewis River	Ariel	2205	44.0	731	24-65[3/]	4,752	7,069	3,090	129,000	1
E. Fk. Lewis River	Heisson	2225	366.8	125	30-65[3/]	741	1,065	462	15,600	29
Cowlitz River	Packwood	2265	1048.0	287	30-65[3/]	1,623	2,411	923	36,600	130
Cispus River	Randle	2325	1221.60	321	30-65[3/]	1,318	1,969	766	20,000	183
Toutle River	Silver Lake	2425	407.3	474	30-65[3/]	1,923	2,936	1,182	37,600	240
Cowlitz River	Castle Rock	2430	20.20	2,238	28-65	8,932	12,484	5,776	139,000	998
Elochoman River	Cathlamet	2475	29.66	65.8	41-65	368	516	219	8,530	18
Columbia River	Mouth	1060	-	259,000	-	239,671	338,362	165,611	-	-

1/ Regulated values for base period (1929-58) with estimated 1970 conditions of development.
2/ Maximum and minimum observed instantaneous values for period of record.
3/ Denotes other short periods of record prior to dates shown.

Average Discharge Figure 522 presents monthly data of discharge generated entirely within the subregion. These flows and the Columbia River inflows are shown in table 292. The generated discharge reaches a maximum in December, is sustained in February by rainfall, and again in May by snowmelt, and gradually recedes to a minimum in August and September. Isopleths showing mean annual runoff for the period 1931-1960 are shown on figure 523.

Average Discharge for Selected Stations In this section of the report detailed data are presented for each of the selected sites listed in table 291. The monthly discharge data were originally available in Geological Survey Water Supply Papers 1318 and 1738, compilations of surface-water records in Part 14. These have been changed to some extent and are presented in tables 293 to 300. The modifications consisted of application of irrigation depletions, an assumed plan of reservoir regulation and extension of records for some sites by correlation with nearby stations. Hydrographs for several conditions of flow at the selected sites are shown on figures 524-531. It should be noted that the supply of water

indicated by the monthly discharge hydrographs is not necessarily available for development, even though it already reflects depletions and storage regulation. Part of the water supply may be committed to downstream uses.

Explanations of the hydrographs and the succeeding graphs are given in the Regional Summary. Examination of the hydrographs indicates that the streams in the subregion have variable runoff patterns; i.e., a high winter peak or a late spring peak in various combinations.

Frequency curves of annual high and low discharges are shown on figures 532 to 539. The slopes of the curves of high flows are moderate for the Lewis and upper Cowlitz Rivers and fairly low for the lower Cowlitz. The low-flow curve slopes are highest for the Elochoman River. The spread of the high-flow curves is fairly great on the Elochoman and upper Cowlitz but moderate for the main Lewis and lower Cowlitz. The spread of the low-flow curves is great for the East Fork Lewis and Elochoman Rivers.

Duration curves for three flow conditions, daily, monthly, and annual, are presented in figures 540 to 547. The monthly and annual discharges used are those of tables 293 to 300, but the daily flows are observed for the period of record as provided in Geological Survey daily summaries. Slope of the annual curve is slightly higher for the Lewis River than for the Cowlitz. Departure of the monthly from the annual curve is noticeably higher for the Lewis River.

Frequency curves of annual peak flows are shown in figures 548 to 553. The curves are for unregulated conditions. The curve with the greatest slope is that for the Cowlitz at Packwood (upper Cowlitz).

Dependable yields of the rivers are given in tables 301 to 308. Each table shows the lowest mean flows for from one to 10 consecutive years in the 30-year base period and their relationship to the 30-year mean. The difference between any two flows is a measure of the reservoir storage capacity required to make the higher flow available. The lowest minimum-year percentage is that for the upper Cowlitz (Packwood), which has a flow equal to 57 percent of the 1929-58 mean. On the other hand, the Lewis River at Ariel, Washington, has a minimum-year flow equal to 65 percent of the base-period mean. The average minimum-year discharge is 60 percent of the base-period mean.

Variations in Discharge Long-term variations in discharge and precipitation are presented in figures 554 and 555. The annual means for the base period and for the entire period of record are shown. Castle Rock is the station presented for precipitation variation. Although the annual precipitation for a given year varied from the mean by as much as 39 percent, the 5-year moving average varied only 18 percent at the most.

The 5-year moving averages are presented in order to indicate trends more clearly. However, the figures do not indicate any long-term trend.

The annual variations in streamflow are generally small and uniform among the selected sites. The maximum annual discharge of all streams in the subregion is generally about 2.3 times the minimum annual discharge, ranging from 2.6 for the Cowlitz at Packwood to 1.9 for the Columbia River.

Annual variations in flow are confirmed by the slopes of the frequency curves. The Elochoman River exhibits generally higher slopes, indicating wider range from year to year.

Seasonal variations in runoff are shown in the hydrographs of figures 524 to 531. Two peaks are shown, one in winter and due primarily to rainfall, and a smaller peak in late spring due to snowmelt. The spring peak for the East Fork Lewis River appears much earlier, and it is negligible for the Elochoman River.

Streamflow Travel Times No information is available on time-of-travel in Subregion 8. However, some idea of the time for the Columbia River may be obtained by comparison with studies for Subregions 6 and 7, and for smaller streams by comparison with studies for Subregions 9 and 10.

River Profiles Profiles for the Lewis and Cowlitz Rivers are shown on figures 556 and 557.

(Narrative continued on page 665)

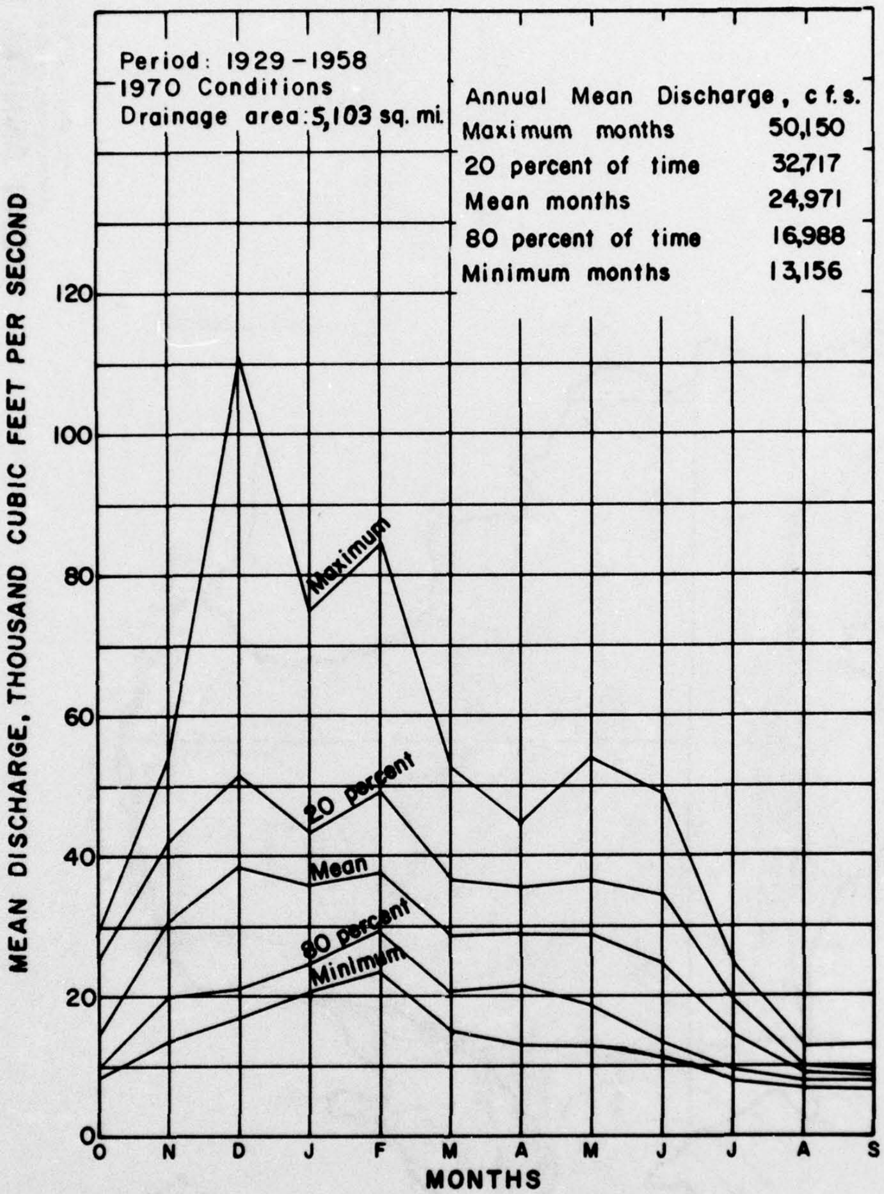
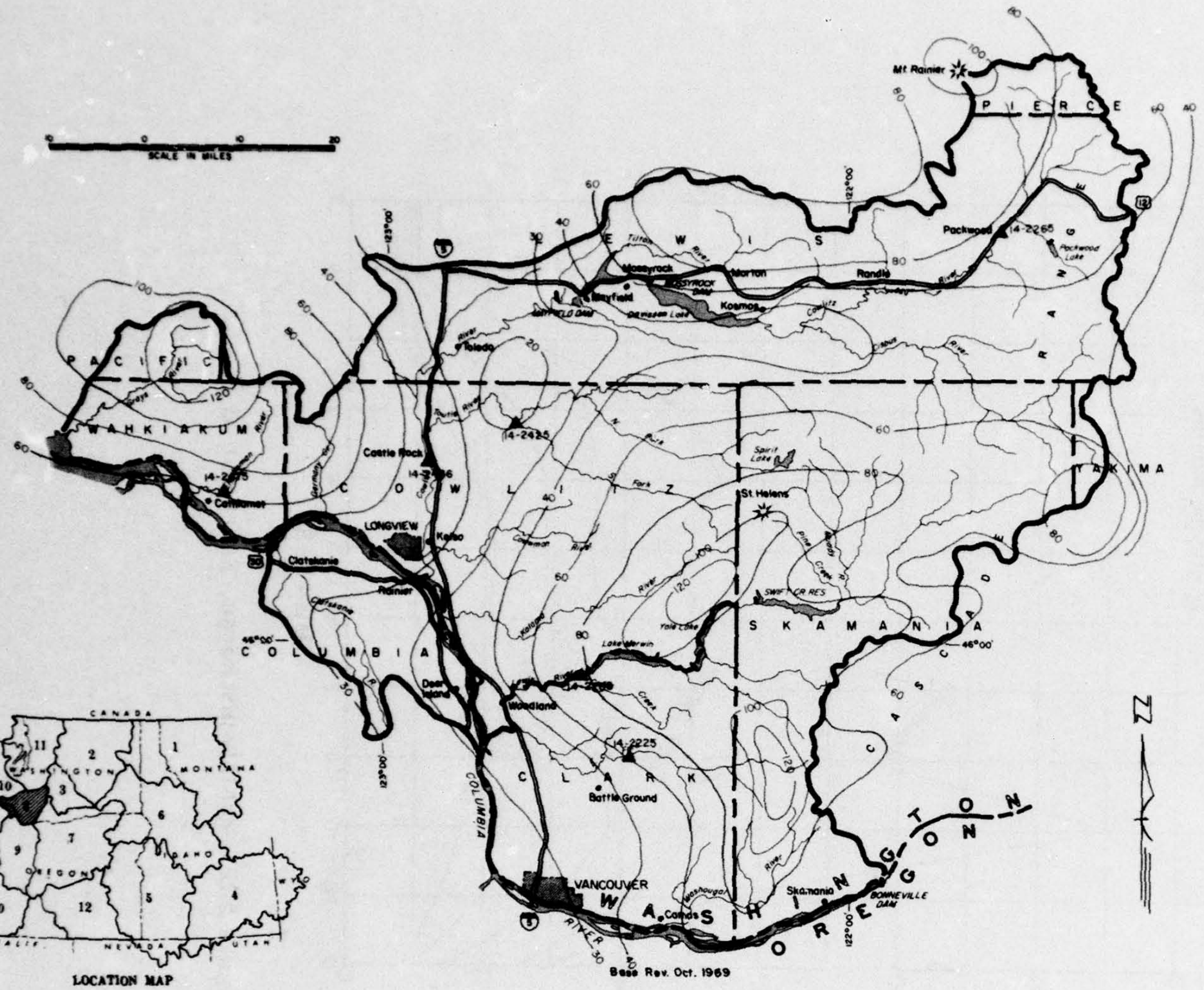


Figure 522. Monthly discharge, Subregion 8.



EXPLANATION

20 — MEAN ANNUAL RUNOFF

▲ STREAM GAGE (RECORDING)

NOTES:

1. MEAN ANNUAL RUNOFF ISOPLETHS HAVE BEEN DRAWN BY U.S. GEOLOGICAL SURVEY, USING OBSERVED STREAMFLOW DATA ADJUSTED TO NATURAL CONDITIONS (1931-1960) AND CORRELATED WITH CLIMATOLOGICAL AND PHYSIOGRAPHIC FACTORS.
2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

LOWER COLUMBIA SUBREGION 8

1968

FIGURE 523

Table 292 - Discharge in Lower Columbia Subregion 1929-58
(Mean Discharge in cfs)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
						Maximum							
Mouth Columbia	217,700	332,200	472,400	417,300	353,400	570,300	403,050	507,100	460,600	325,505	219,600	173,855	371,084
Inflow	189,195	278,905	362,175	342,315	268,725	417,905	358,450	453,150	311,870	301,190	206,830	160,700	320,934
Subregion	28,505	53,295	110,225	74,985	84,675	52,395	44,600	53,950	48,830	24,315	12,870	13,155	50,150
						20 Percent							
Mouth Columbia	176,430	257,430	315,400	330,550	318,800	414,000	324,550	388,900	366,500	246,595	159,200	144,695	286,398
Inflow	151,215	215,665	263,790	297,225	270,085	377,545	289,070	352,260	332,075	227,260	149,220	134,955	253,681
Subregion	25,215	41,665	51,610	43,325	48,715	36,465	35,480	36,640	34,425	19,335	9,980	9,740	32,717
						Mean							
Mouth Columbia	158,989	211,609	258,828	284,734	270,719	321,858	278,544	311,713	290,184	200,420	147,633	140,806	239,677
Inflow	144,444	180,994	220,818	249,049	233,324	293,398	249,784	282,998	265,594	185,690	138,453	131,836	214,706
Subregion	14,545	30,615	38,010	35,685	37,395	28,460	28,760	28,715	24,590	14,730	9,180	8,970	24,971
						80 Percent							
Mouth Columbia	141,730	164,610	189,140	232,430	221,510	236,390	227,395	216,200	181,900	141,500	136,999	132,935	185,228
Inflow	131,985	145,135	168,085	208,365	192,315	215,660	205,560	197,545	168,050	132,260	129,004	124,920	168,240
Subregion	9,745	19,475	21,055	24,065	29,195	20,730	21,835	18,655	13,850	9,240	7,995	8,015	16,988
						Minimum							
Mouth Columbia	137,390	150,070	128,960	187,117	192,360	196,730	154,850	173,800	157,600	132,600	132,100	120,595	155,342
Inflow	128,990	136,640	111,580	166,752	169,670	181,350	141,235	160,235	146,310	124,595	124,960	113,380	142,186
Subregion	8,400	13,430	16,380	20,365	23,690	15,380	13,615	13,565	11,290	8,005	7,140	7,215	13,156

Table 293 - Modified Mean Discharges, in CFS, Lewis River at Ariel, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1790	1070	1028	
1929	3514	7393	4686	6756	3108	6551	2427	2033	2610	1236	1040	899	3521
1930	1994	4273	4526	6076	10836	7655	967	651	650	650	651	650	3298
1931	650	5536	2336	8315	6238	8771	4987	651	650	651	900	1581	3439
1932	4150	7420	8385	8603	7780	9465	8322	650	2240	2550	1360	1134	5172
1933	2814	12427	9091	8099	5822	2420	4069	8520	10600	4420	1810	2413	6042
1934	6190	5899	26701	16670	4830	7250	4435	2710	1450	1170	980	1013	6608
1935	5484	12692	9676	8335	7583	5425	2873	658	4290	2010	1160	1184	5112
1936	2394	5563	3706	12477	7152	8685	4915	650	650	753	1280	1064	4107
1937	2084	4263	5516	4966	4058	9757	9257	1929	3770	1718	1640	1089	4171
1938	1552	13327	10946	11235	7334	1627	5383	4646	3440	1660	1170	1118	5287
1939	2544	7333	6066	9082	8285	7941	650	650	650	652	1140	1064	3838
1940	2374	4843	8716	6923	10717	8547	686	1443	1295	1198	1189	685	4051
1941	2382	7593	5406	8303	5249	3301	650	650	1663	720	650	650	3101
1942	2569	7818	9760	7492	6288	5104	650	650	650	654	1220	929	3649
1943	2304	11517	9990	6224	6753	1350	2094	5270	4580	2210	1200	1049	5045
1944	3224	6303	4506	7396	5498	5342	787	650	720	729	650	1273	3090
1945	2316	5694	5384	8993	8297	8748	5460	650	650	650	650	819	4027
1946	2263	9014	9062	10752	8614	1467	2078	7040	5700	3690	1440	1183	5192
1947	3744	10320	13614	7740	8558	1070	5933	3200	2450	1510	1060	1399	5050
1948	7506	9208	7188	8200	7195	1121	5469	8040	5280	1970	1210	1354	5313
1949	3364	8742	7314	5214	7352	2656	2059	9770	4670	2280	1180	1179	4690
1950	3304	9820	8557	7510	9710	6040	8720	7940	8010	3920	1790	1469	6399
1951	6287	10541	11082	8831	8923	4100	6320	6540	3570	1780	1190	1294	5872
1952	7586	8551	8323	4516	8666	1038	4386	6890	3810	2010	1180	1064	4835
1953	1874	4263	3426	15667	12746	2280	4880	4867	5300	2720	1480	1479	5082
1954	3074	9045	11690	8892	9840	1589	6880	6370	6320	3710	1740	1426	5890
1955	3390	8317	6634	6020	7755	3169	8411	650	3199	3990	1760	1739	4586
1956	8184	13191	11406	10050	5335	5269	8255	9040	6850	3790	1940	1514	7069
1957	4774	8374	9440	4610	7051	2872	6166	5720	2790	1441	1115	961	4610
1958	2564	7453	9196	9405	10698	1731	5992	5300	2860	2010	1180	1190	4965
Mean	3548	8223	8410	8445	7610	4745	4472	3814	3379	1948	1232	1196	4752

Table 294 - Observed Mean Discharges, in CFS, East Fork Lewis River near Heisson, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										110	55	75	
1929	475	820	1010	780	450	975	1080	650	410	120	80	65	576
1930	54	55	1010	615	2130	731	455	557	334	109	66	60	505
1931	145	488	437	1030	672	1460	1200	198	282	141	63	77	515
1932	514	1340	1080	1480	1140	2430	1340	542	219	95	61	50	858
1933	191	1800	1740	1780	887	1650	949	1250	914	203	96	365	986
1934	925	886	3957	2156	424	894	541	328	113	72	49	58	876
1935	573	1981	1839	1383	834	1045	902	440	163	99	57	48	780
1936	74	285	622	2184	919	1153	710	648	592	189	82	67	628
1937	64	54	1279	324	1172	1531	1818	657	761	195	98	116	668
1938	295	2180	2222	1402	938	1431	1341	473	155	70	50	46	883
1939	156	957	1191	1409	1495	1199	551	241	352	146	67	69	648
1940	192	257	1532	674	2161	1309	819	587	117	72	47	60	648
1941	257	851	911	1009	471	405	312	520	276	112	103	555	482
1942	579	834	2067	601	1131	614	468	770	659	237	100	60	675
1943	145	2252	1918	950	1724	1078	1243	527	367	149	85	53	866
1944	337	421	768	608	812	695	830	408	422	119	66	84	462
1945	95	382	556	1446	1413	1289	1105	1068	259	95	59	162	657
1946	127	1523	1312	1486	1325	1334	717	407	311	248	86	69	742
1947	511	1709	2294	1241	1262	732	976	219	379	170	83	105	803
1948	1104	1616	1014	1441	1332	947	1032	996	267	126	87	143	840
1949	355	1407	1812	365	1684	1274	839	777	169	95	60	76	736
1950	316	1005	1349	1593	2169	1818	1298	708	331	119	65	64	895
1951	801	1884	1808	2101	1531	1000	728	452	178	81	52	79	888
1952	1318	1027	1664	749	1398	973	900	523	225	145	63	47	751
1953	40	56	663	3460	1532	1036	697	778	503	138	121	82	757
1954	254	1155	2390	1606	1837	817	953	325	607	266	113	102	863
1955	299	935	1149	953	1115	760	1489	950	523	292	116	120	722
1956	1118	2189	2249	1952	801	1921	1196	601	375	135	127	87	1065
1957	632	813	1551	450	1229	1613	1037	371	247	104	75	50	678
1958	142	564	1888	1495	1693	643	1286	279	180	110	54	73	694
Mean	402	1057	1509	1300	1256	1158	960	575	356	142	78	103	741

Table 295 - Observed Mean Discharges, in CFS, Cowlitz River at Packwood, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										616	417	381	
1929	760	990	970	710	270	950	1630	3370	3170	1560	580	340	1275
1930	298	201	706	512	2230	1180	2300	2150	2140	1120	616	431	1150
1931	354	599	684	1650	1120	1310	1900	3050	1860	860	564	381	1200
1932	543	1210	1050	1180	1520	2090	2050	3030	3910	2400	929	505	1700
1933	646	3390	1580	1440	396	796	1460	2560	5180	4260	1690	939	2030
1934	2586	1939	6025	3572	1499	3157	2662	2229	1351	858	618	397	2254
1935	1901	3205	1679	1709	1617	954	1172	2968	3904	1868	789	600	1862
1936	411	401	603	1318	614	1270	2393	4547	3922	1459	752	504	1518
1937	405	326	913	364	396	1081	1884	3204	4898	1963	757	551	1398
1938	601	2708	2002	1606	688	938	2572	3319	2879	1159	553	451	1625
1939	441	804	1601	1384	658	1173	2080	3401	2593	1648	759	467	1423
1940	400	576	2037	1134	1639	1753	1620	2443	1408	772	545	397	1227
1941	499	921	1270	971	689	811	1160	1590	1130	752	522	745	923
1942	1092	1411	2278	761	753	700	1482	1976	2506	1389	677	425	1290
1943	330	2167	1666	1036	944	1122	2555	2729	3495	2509	806	522	1657
1944	435	574	1272	758	841	939	1200	2071	1802	862	504	586	987
1945	520	773	941	1882	1668	854	1045	3340	2243	1214	605	753	1318
1946	999	1167	1621	1395	982	1154	1948	4232	4054	2770	995	569	1829
1947	966	1912	3058	1324	1581	1413	2203	3338	2453	1229	674	646	1734
1948	2451	2295	1750	1270	1110	974	1249	3337	5041	1844	860	572	1896
1949	933	1192	832	479	810	1270	2166	5209	4386	2750	1027	614	1811
1950	1001	3077	1532	1421	1514	1950	1757	2937	4902	3942	1544	700	2191
1951	1905	2966	3429	1462	2499	996	2133	3169	2985	1491	657	510	2011
1952	1671	1386	1240	487	1207	736	2273	3410	2885	1796	730	386	1516
1953	327	196	319	3651	2009	816	1422	2748	2884	2880	1050	597	1575
1954	613	1296	2587	1170	1692	1141	1625	3367	3822	3699	1478	795	1943
1955	894	1822	1105	951	950	495	1010	2791	5128	3028	1095	648	1660
1956	2683	3533	2716	1475	634	931	2456	4571	4524	3451	1204	688	2411
1957	960	1355	2919	728	1032	1557	1950	3750	2683	1149	638	518	1608
1958	490	620	1374	1545	1816	826	1603	3874	2717	1153	691	485	1430
Mean	937	1500	1725	1311	1190	1177	1832	3157	3328	1928	830	557	1623

Table 296 - Observed Mean Discharges, in CFS, Cispus River near Randle, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										680	480	370	
1929	520	780	880	600	360	840	1650	2800	2050	890	450	305	1010
1930	308	265	742	551	2140	1180	1920	1540	1100	609	394	311	930
1931	327	398	416	1050	1160	1290	2100	1960	967	620	413	340	919
1932	471	908	939	1020	995	1940	2140	3140	2680	1160	554	371	1360
1933	453	2940	1580	1320	601	1010	1610	2700	4320	2010	843	611	1670
1934	1248	1497	5567	3759	1517	2273	2004	1390	880	605	408	306	1797
1935	861	2567	1734	1357	1444	913	1263	2665	2229	960	532	344	1403
1936	266	294	454	1253	596	1123	2466	3674	2728	955	546	391	1230
1937	319	262	850	396	328	1154	2415	3143	3221	1261	529	460	1198
1938	414	2062	2317	2025	833	1234	2378	2964	2021	796	470	378	1494
1939	374	697	1251	1232	754	1308	2105	2456	1559	836	448	348	1116
1940	306	320	1782	1153	1785	1948	1832	1805	840	501	388	331	1081
1941	362	671	1248	1001	788	844	1021	1331	784	505	374	485	785
1942	786	1091	2581	816	902	721	1531	1594	1468	793	469	349	1093
1943	298	1783	1555	1148	1115	1359	3252	2439	2194	1305	647	428	1458
1944	449	573	804	634	779	761	1208	1651	1059	537	374	369	766
1945	331	527	702	1145	1435	917	1196	2783	1582	707	420	393	1009
1946	334	976	1693	1712	971	1187	1856	3872	2873	1649	661	431	1522
1947	641	1764	3548	1306	2127	1370	1692	1907	1176	680	458	409	1419
1948	1579	1896	1424	1465	1052	1007	1413	3175	3455	1097	628	502	1558
1949	673	1004	913	564	981	1453	8220	4292	2458	1191	632	484	1407
1950	534	1359	1152	1189	1660	2021	1779	2894	3772	1975	796	520	1635
1951	1204	2451	2948	1514	2458	976	2030	2745	1788	875	538	407	1655
1952	1135	1300	1523	659	1216	841	2152	2656	1724	934	510	374	1251
1953	289	251	350	2893	1773	883	1434	2453	2239	1472	646	443	1258
1954	486	1038	2299	1370	1906	1345	1821	2981	2873	2046	918	583	1637
1955	619	1227	1073	900	999	600	1196	2128	3521	1598	700	470	1251
1956	1418	2586	3043	1608	782	1074	2488	4166	3346	1812	761	499	1969
1957	623	1003	1806	721	1203	1751	1826	2756	1301	663	461	363	1207
1958	377	543	1178	1409	1992	998	1700	2736	1496	682	475	368	1157
Mean	600	1168	1612	1259	1146	1210	2057	2627	2123	1057	548	412	1318

Table 297 - Observed Mean Discharges, in CFS, Toutle River near Silver Lake, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										620	415	385	
1929	1030	2190	2220	1460	980	1670	2020	2100	1540	770	430	325	1395
1930	368	301	2060	1320	4330	2010	1860	1890	1280	558	348	308	1370
1931	492	864	1070	2380	1890	2590	3570	1420	1150	739	372	395	1410
1932	1050	2380	2640	3150	2410	4950	3670	2430	2060	1070	553	426	2230
1933	703	4890	3980	4050	1850	3450	2280	2740	3740	1810	864	1040	2620
1934	1891	2411	12560	6581	2150	2504	1796	1297	731	473	377	382	2783
1935	1840	4683	3892	3988	2669	2240	1967	1872	1467	863	514	457	2201
1936	465	786	1223	4708	2288	2676	2173	2641	2559	945	494	464	1786
1937	450	379	2421	1044	1918	2639	4035	2641	2958	1120	565	600	1726
1938	653	4307	4518	3889	2062	2615	2767	2151	1308	590	402	367	2136
1939	578	1729	2612	3067	3307	2605	1885	1485	1380	760	411	392	1675
1940	455	588	3092	1736	4556	3347	2396	2092	703	444	364	407	1673
1941	556	1443	2109	2119	1312	1129	1045	1481	976	506	430	1091	1182
1942	1434	1787	4608	1618	2064	1467	1335	1604	1911	921	501	360	1634
1943	460	4014	3553	2202	3181	2334	3249	1723	1576	942	518	406	2000
1944	780	1090	2073	1919	1783	1537	1781	1507	1201	520	334	463	1247
1945	419	1668	1368	2648	3090	2542	2456	3190	1496	723	429	700	1718
1946	633	3237	3939	4229	3113	2823	2208	2435	2304	1583	590	474	2293
1947	1261	3385	6822	3116	3519	1924	2106	1214	1128	634	392	501	2160
1948	2362	4387	2756	3505	3185	2323	2595	3444	2300	925	662	665	2421
1949	1131	2842	3655	1219	3893	2949	2256	3117	1500	833	497	460	2017
1950	910	2453	3102	3949	4834	4855	3225	2517	2711	1387	614	486	2573
1951	1929	4084	4583	4189	4379	2215	2271	1950	1187	596	407	414	2338
1952	2281	2549	3353	1661	3098	1935	2315	2228	1375	816	443	362	1864
1953	314	369	1219	6657	3526	1876	1871	2250	1782	1075	581	481	1827
1954	958	2225	5641	4098	5000	2325	2605	1895	2346	1478	713	634	2478
1955	882	2380	2432	2315	2908	1800	3026	2360	2912	1740	689	564	1991
1956	2505	5492	6429	4667	1774	3770	3069	2800	2192	1283	672	492	2936
1957	1286	1817	3702	1282	2717	3775	2535	2006	1129	557	432	333	1794
1958	471	1130	3644	3520	3880	1738	2841	1693	1204	616	417	381	1782
Mean	1018	[illegible]	2836	3076	2922	2554	2440	2139	1737	909	500	494	1923

Table 298 - Modified Mean Discharges, in CFS, Cowlitz River at Castle Rock, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										4280	2451	2560	
1929	3769	6065	6190	5326	15519	9347	9547	3718	10219	4657	2431	2431	6601
1930	2681	4599	5295	9199	11096	8385	11442	8122	5806	3381	2421	2414	6237
1931	3137	7310	8082	9451	10253	14690	10662	9022	6276	3422	3034	4280	7468
1932	4424	17786	16279	16246	12752	16536	4885	4540	9404	6946	3062	3030	9657
1933	5461	19523	29745	20134	11339	7205	6481	10880	15929	8516	4058	4119	11949
1934	9776	18066	41094	28454	9023	11896	9940	7528	4623	3373	3253	2784	12484
1935	5914	15916	11843	17810	15562	8003	6200	7570	11371	5515	2534	2846	9223
1936	2456	4694	5879	10530	13946	11319	12937	9175	13800	7907	2510	2814	8164
1937	2595	10510	13494	10254	10634	12066	11572	8793	12150	5660	3051	3466	8687
1938	2957	15894	14871	16416	16770	5745	6988	11500	8731	4181	2555	2557	9097
1939	2939	7418	11833	10794	19301	11637	7541	6004	7044	4081	2449	2497	7795
1940	2858	6600	11411	8680	16372	8865	4748	5656	3724	2503	2495	3093	6417
1941	3530	7912	12524	7515	12249	5413	3654	3993	4580	3102	2440	2406	5776
1942	2454	12878	17562	7968	15962	7217	6790	3924	6661	4729	2604	2602	7612
1943	2904	13776	13097	9599	14159	4348	10907	9682	9681	6007	2710	2807	8306
1944	2965	6786	6695	8507	14820	8840	7372	5570	3729	2716	2445	3925	6197
1945	2916	11318	13822	15758	13341	15567	12951	4570	4500	3884	2623	2469	8643
1946	3340	12325	19008	11921	17480	4971	6784	14213	11506	7407	3088	2983	9585
1947	7191	17125	21703	13776	16079	5762	9697	12155	8162	3891	2712	2870	10093
1948	9347	17941	14608	10304	15476	6456	7286	16090	14200	5383	2961	3326	10281
1949	4795	13220	14675	10085	20424	9550	10810	18160	12190	6791	3429	3262	10615
1950	5865	16763	14615	15292	19975	9683	12569	13414	15502	9145	3847	3190	11655
1951	8776	18557	21040	12425	16869	6710	11790	12402	8108	4243	2572	2441	10494
1952	6680	9415	9335	12855	17868	4835	6242	12746	8646	5018	2672	2556	8239
1953	3252	7093	10470	24512	22778	5584	6178	9634	11401	7893	3431	3307	9627
1954	4019	11396	19482	12625	17468	5279	11474	13947	13430	10004	4332	3608	9023
1955	6843	16948	14937	13745	14437	8490	11791	5100	17627	9241	3771	3557	10540
1956	9775	20245	21664	11411	8766	8723	14202	16650	12935	7774	3621	3213	11581
1957	5033	9827	17943	9722	16032	5065	12079	11800	7349	3461	2564	2633	8625
1958	2910	7401	13140	14155	19779	4842	8010	12816	7479	5025	2862	2940	8447
Mean	4719	12177	15078	12436	14884	8434	8774	9646	9559	5515	2951	3014	8932

Table 299 - Observed Mean Discharges, in CFS, Elochoman River near Cathlamet, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										40	35	55	
1929	133	250	417	320	362	435	323	165	185	55	23	16	224
1930	19	15	441	270	865	347	256	282	126	30	18	18	224
1931	49	245	358	909	415	910	459	76	101	48	16	50	303
1932	355	843	801	1012	846	916	450	112	48	32	23	16	454
1933	81	1048	1108	1289	794	871	288	327	218	44	23	105	516
1934	216	366	2469	1326	175	396	270	206	48	30	21	39	463
1935	436	1099	924	1075	447	716	287	96	46	41	18	39	435
1936	39	165	413	1473	692	613	216	213	206	80	27	27	347
1937	15	12	581	330	1091	337	536	227	169	60	32	34	285
1938	135	1359	1208	465	575	711	290	128	41	21	14	11	413
1939	55	515	550	942	1061	439	120	50	110	44	14	11	326
1940	55	95	1039	455	1252	662	249	350	46	23	14	16	355
1941	151	343	415	563	232	186	137	207	98	49	46	194	219
1942	251	485	926	326	486	324	170	175	234	112	58	36	298
1943	123	990	988	389	926	367	496	168	118	59	43	31	387
1944	105	206	563	463	417	379	357	151	108	55	38	70	242
1945	90	347	302	756	712	765	398	199	83	44	30	78	315
1946	66	704	898	988	980	590	402	128	103	100	44	46	417
1947	195	792	1128	747	730	335	308	111	112	70	43	60	384
1948	549	704	526	732	715	488	369	406	111	57	43	73	397
1949	176	679	1215	237	1160	537	211	203	70	46	34	37	379
1950	140	682	950	691	1331	1146	568	208	85	52	51	40	490
1951	411	818	1032	1053	1299	540	245	111	56	35	25	44	467
1952	481	492	728	479	761	475	276	113	64	42	31	25	329
1953	234	44	406	1622	805	371	275	244	138	62	47	43	359
1954	168	571	1202	878	1142	415	490	112	135	80	51	80	439
1955	147	551	565	613	569	576	628	199	99	87	52	57	343
1956	482	1181	1250	983	357	1072	443	117	100	53	46	49	513
1957	378	409	948	301	670	693	374	113	86	46	41	26	341
1958	58	275	966	794	738	332	540	157	85	42	34	54	337
Mean	193	542	843	749	753	564	397	178	108	53	33	47	368

Table 300 - Modified Mean Discharges, in CFS, Columbia River at Mouth, Oregon-Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										275843	143159	130807	
1929	141790	171370	190610	215610	219610	212900	213570	180900	184300	137100	133740	136160	178137
1930	137940	150070	216560	193500	288770	196730	179200	176400	157600	132600	132100	132275	174478
1931	139240	158350	175580	204710	192360	229600	154850	173800	162100	136600	132940	127200	165611
1932	142240	198190	128960	275110	228760	322500	268300	337500	305400	146800	139300	142810	219656
1933	154670	227400	262250	320670	325410	319680	256200	368600	460100	265700	176000	165350	275169
1934	188300	228500	472400	417300	249101	450600	387545	334700	234300	151300	140600	141275	282993
1935	148940	237500	286160	301870	260200	263080	238585	281700	281600	189400	144200	140045	231107
1936	145850	164610	185330	345950	221510	237930	232895	337200	250700	142900	137500	138720	211758
1937	141490	159360	193300	187170	243970	246390	290830	216200	208800	148200	142590	141880	193349
1938	146340	257560	296660	319820	273210	347200	307800	362700	303400	234400	140630	138250	260656
1939	145190	182410	205550	252140	247700	254400	227395	222900	192200	142700	138900	139215	195891
1940	140250	157490	206910	243070	307230	296485	242395	223600	175295	139300	140640	139250	200993
1941	142240	190520	208805	241690	200005	198700	215050	185300	181300	141500	137240	141900	182021
1942	152000	203800	315400	248090	268200	236390	237625	245400	274400	165000	142200	140185	219057
1943	142910	257430	319820	330960	316695	361100	399695	426900	312100	246300	152100	141060	283922
1944	155820	182300	188450	200250	219245	199510	196900	177500	170300	137500	132640	128030	174037
1945	137390	167480	178720	237340	260790	245030	229325	274400	181900	141800	139140	137490	194234
1946	143480	223710	279080	316600	242590	344800	271350	345700	311300	211302	141100	144695	247975
1947	164450	257350	356800	268970	278000	347500	302950	344100	294500	201000	136999	136350	257414
1948	217700	293000	255400	330100	284400	453230	313450	329000	423100	284100	173100	158645	292935
1949	164480	219700	264990	232430	336740	314890	291250	416700	331800	144500	139400	132935	249143
1950	151320	189560	240940	317620	334500	481500	349750	390400	422300	328500	166300	145820	243211
1951	213300	332200	330030	359800	348600	538000	394400	371000	306100	246595	162100	142495	312043
1952	209100	238390	305820	270080	309405	354202	324550	412600	308600	229595	136500	131100	269162
1953	141730	155090	189140	388000	240200	289505	239300	355245	367300	228400	148700	137420	240002
1954	153910	237050	344380	330550	318800	368400	288700	348700	381800	325505	219600	173855	290938
1955	176430	222700	242580	270090	235320	254240	265950	256200	365600	288800	158300	144500	240059
1956	203200	314100	374400	369200	258880	570300	403050	507100	460600	291100	159200	149215	338362
1957	172410	201800	280160	237590	258770	414000	308050	388900	366500	183500	133740	135885	256775
1958	156030	169900	273420	316960	353400	308000	326250	361000	331100	251190	151625	120595	259956
Max.	217700	332200	472400	417300	353400	570300	403050	507100	460600	325505	219600	173855	338362
Min.	137390	150070	128960	193500	192360	196730	154850	173800	157600	132600	132100	120595	165611
Total	4770140	6348890	7785605	8542387	8122378	9656702	8357160	9352345	8706395	6013187	4429124	4224606	7191044
Mean	158989	211609	258828	284734	270719	321858	278544	311713	290184	200420	147623	140806	239677

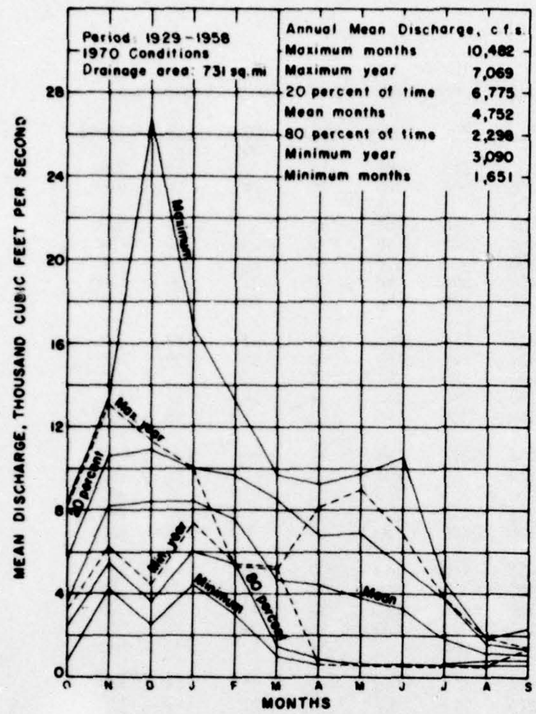


Figure 524 Monthly discharge, Lewis River at Ariel, Washington

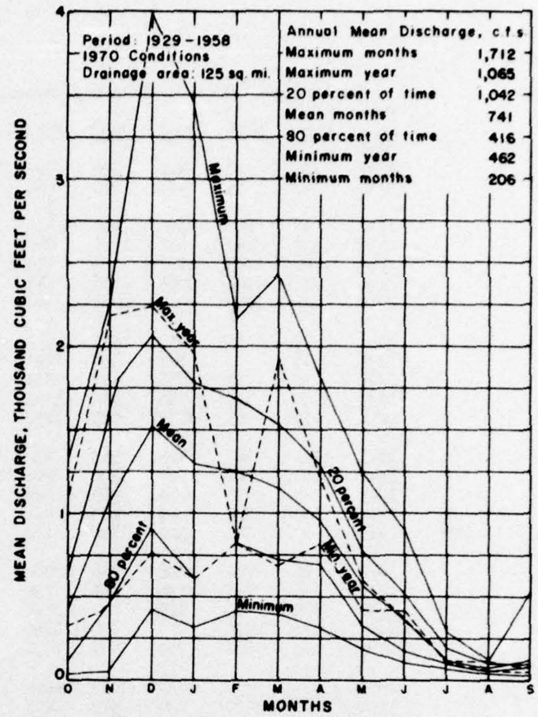


Figure 525 Monthly discharge, East Fork Lewis River nr. Heisson, Washington

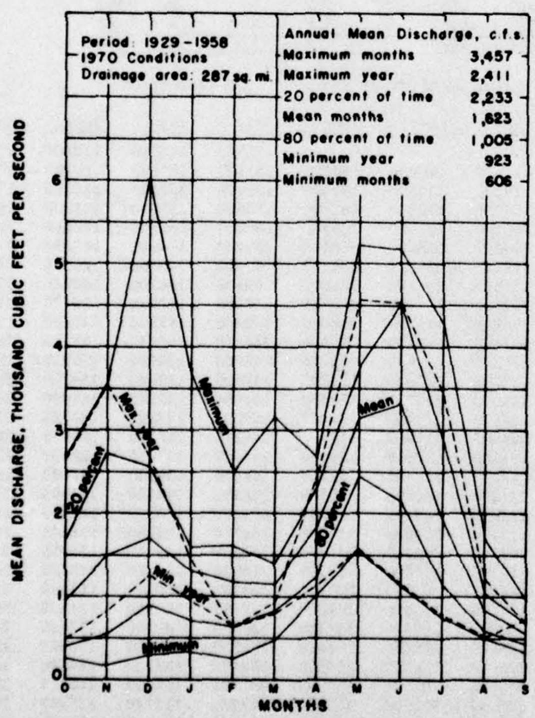


Figure 526 Monthly discharge, Cowlitz River at Packwood, Washington

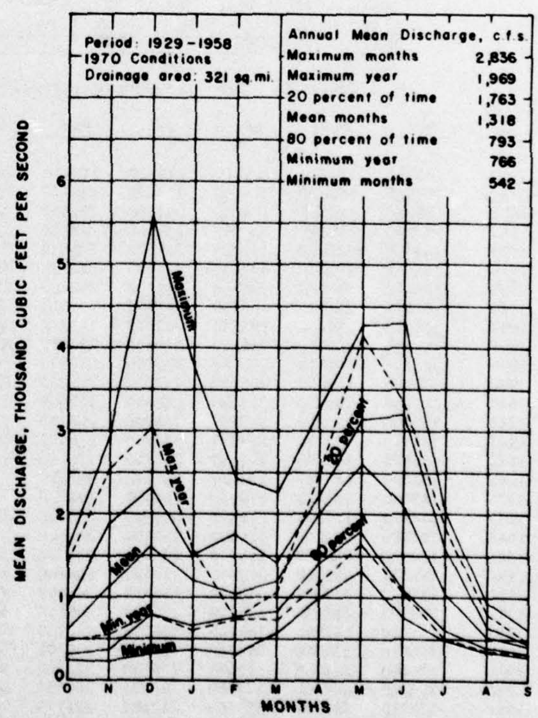


Figure 527 Monthly discharge, Cispus River near Randle, Washington

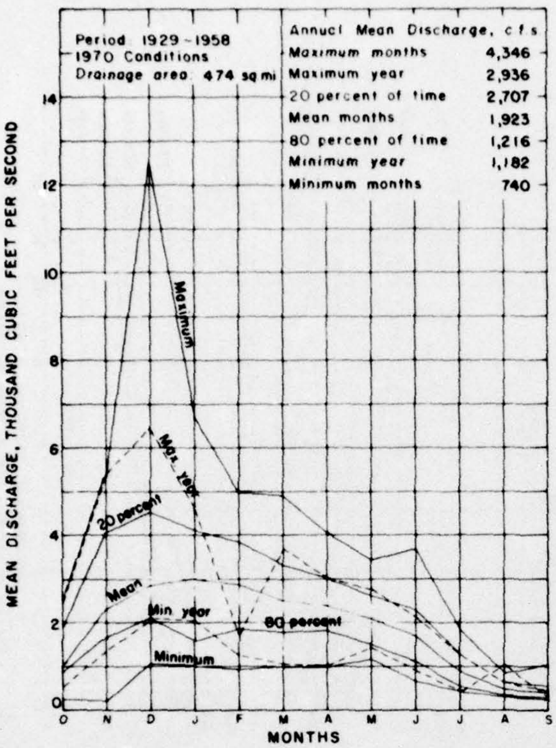


Figure 528 Monthly discharge, Toutle River near *Silver Lake, Washington*

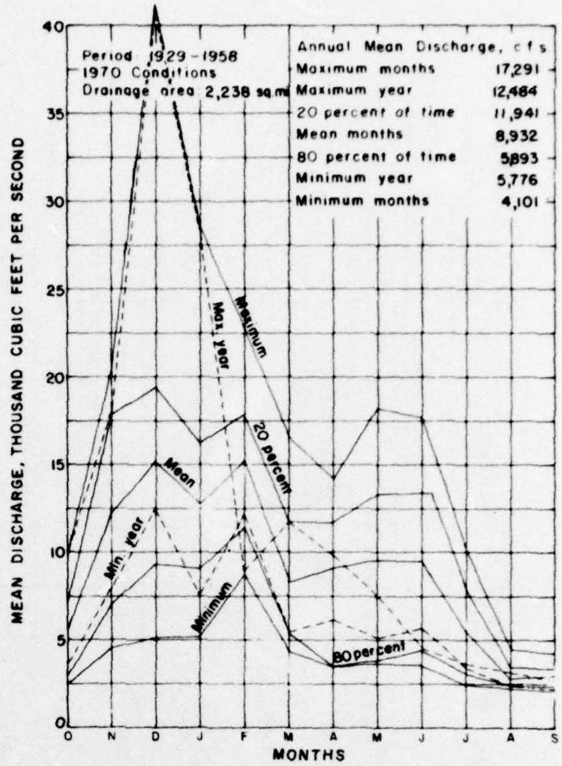


Figure 529 Monthly discharge, Cowlitz River at Castle Rock, Washington

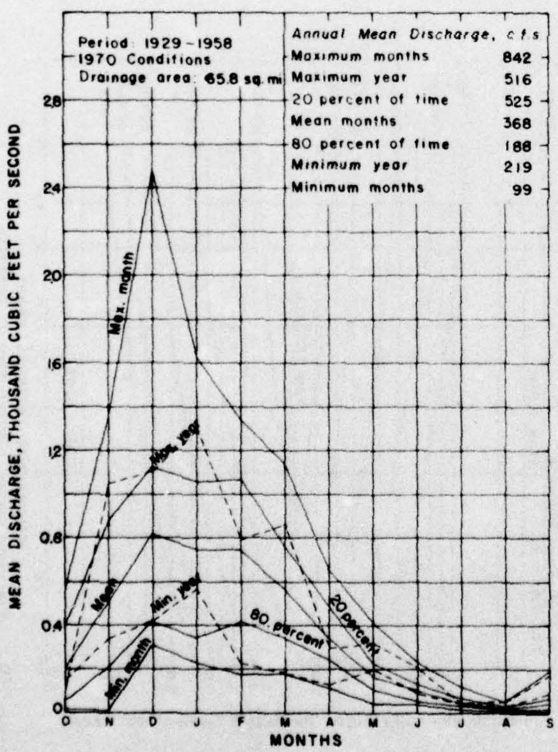


Figure 530 Monthly discharge, Elochoman River near Cathlamet, Washington

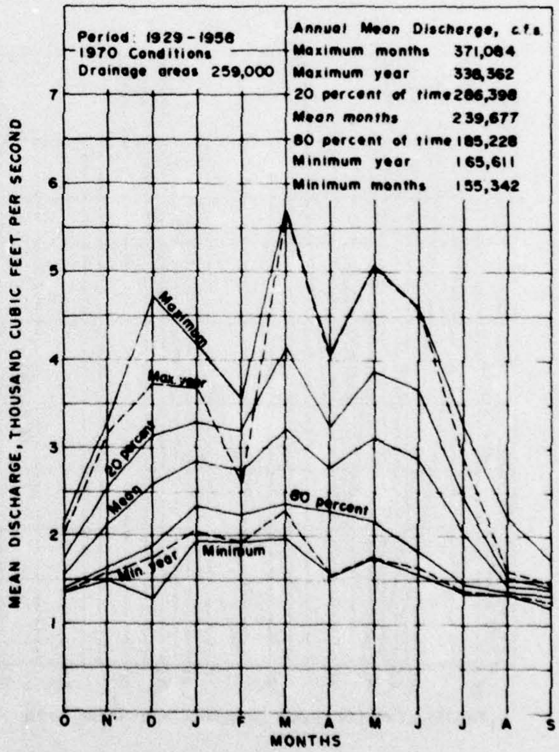


Figure 531 Monthly discharge, Columbia River at Mouth

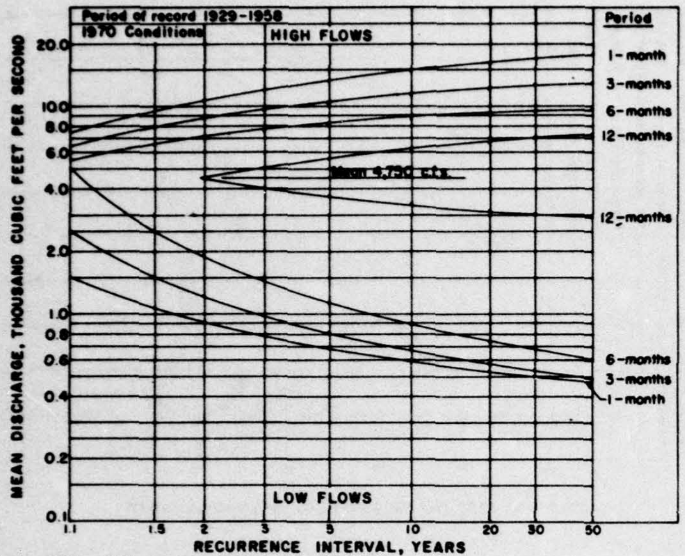


Figure 532 Frequency curves, Lewis River at Ariel

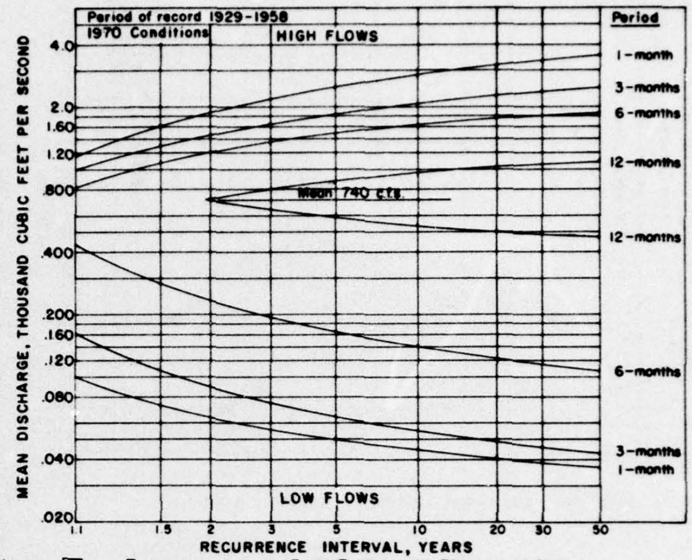


Figure 533 Frequency curves, East Fork Lewis River nr. Heisson

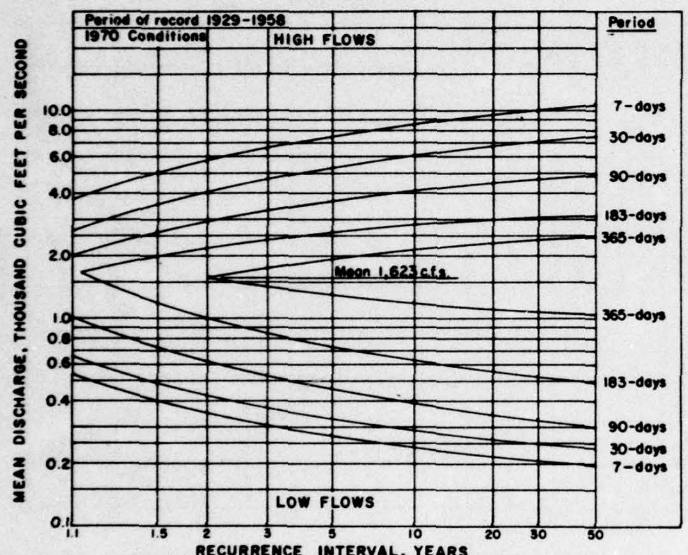


Figure 534 Frequency curves, Cowlitz River at Packwood

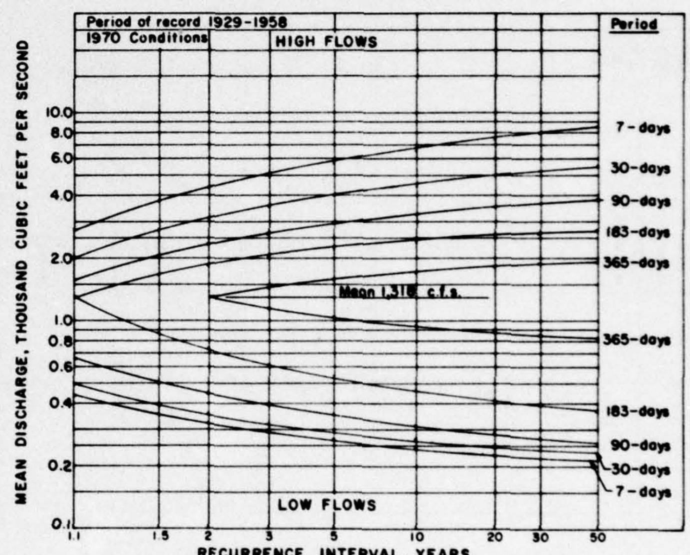


Figure 535 Frequency curves, Cispus River Nr. Randle

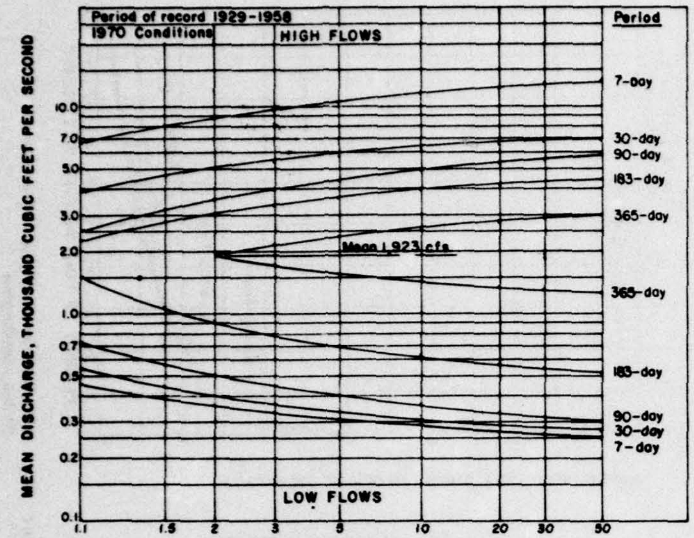


Figure 536 Frequency curves, Toutle River Nr. Silver Lake

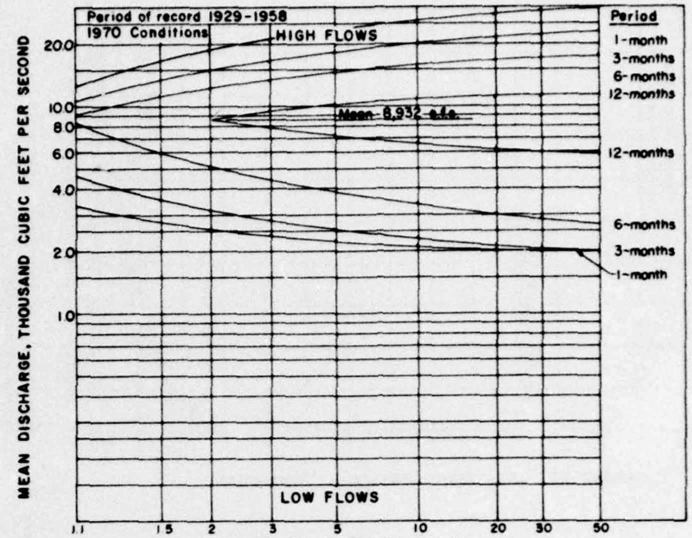


Figure 537 Frequency curves, Cowlitz River at Castle Rock, Washington

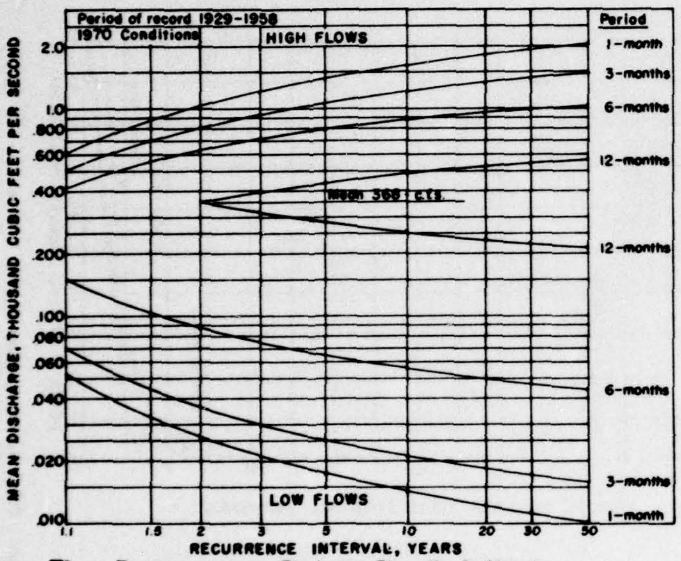


Figure 538 Frequency curves, Elochoman River Nr. Cathlamet

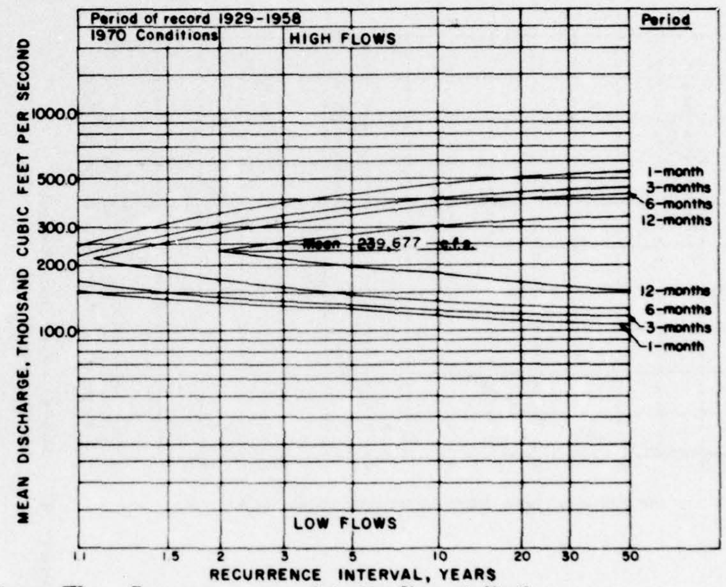


Figure 539 Frequency curves, Columbia River at Mouth

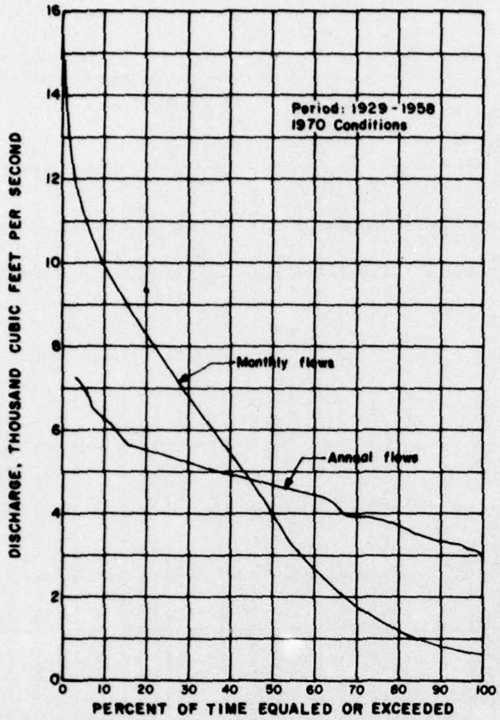


Figure 540 Duration curves, Lewis River at Ariel, Washington

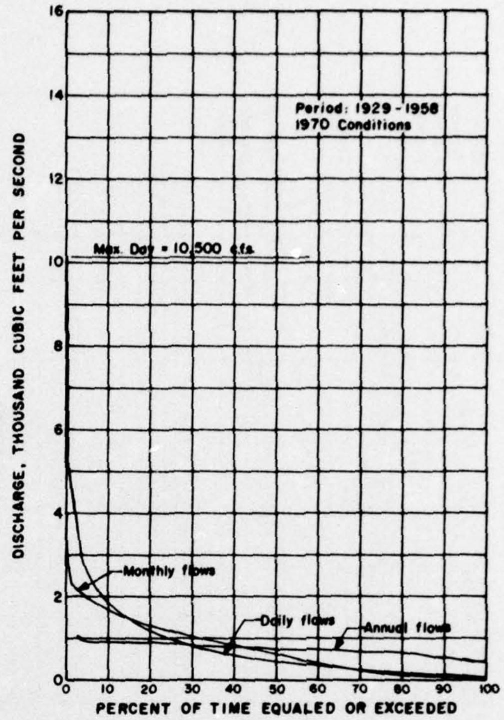


Figure 541 Duration curves, East Fork Lewis River near Heisson, Washington

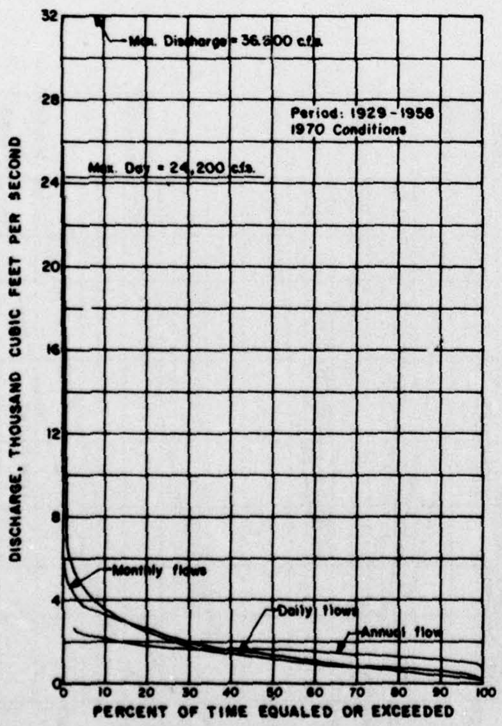


Figure 542 Duration curves, Cowlitz River at Packwood, Washington

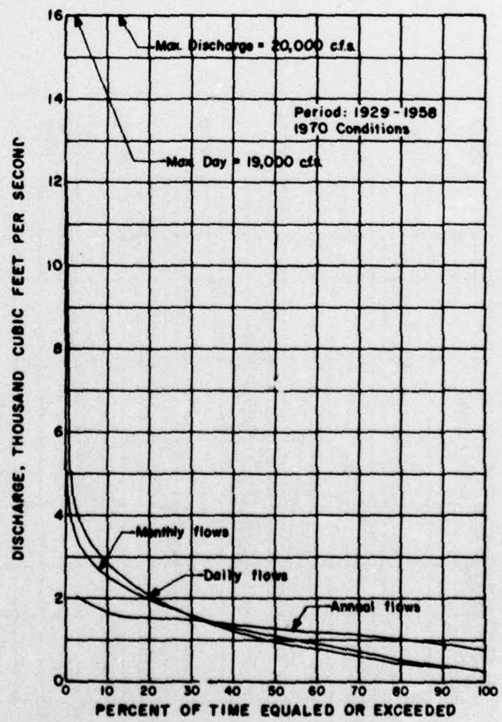


Figure 543 Duration curves, Cispus River near Randle, Washington

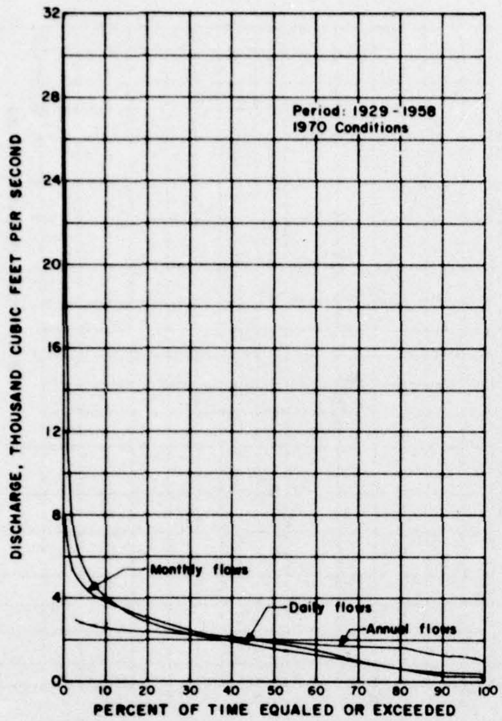


Figure 544 Duration curves, Toutle River near Silver Lake, Washington

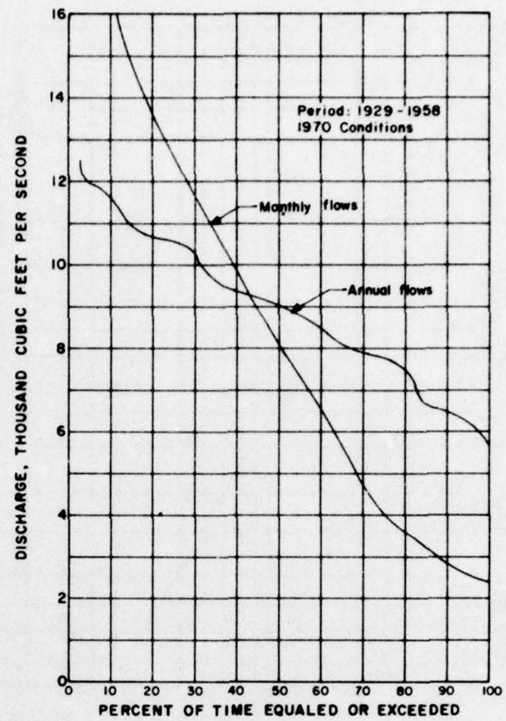


Figure 545 Duration curves, Cowlitz River at Castle Rock, Washington

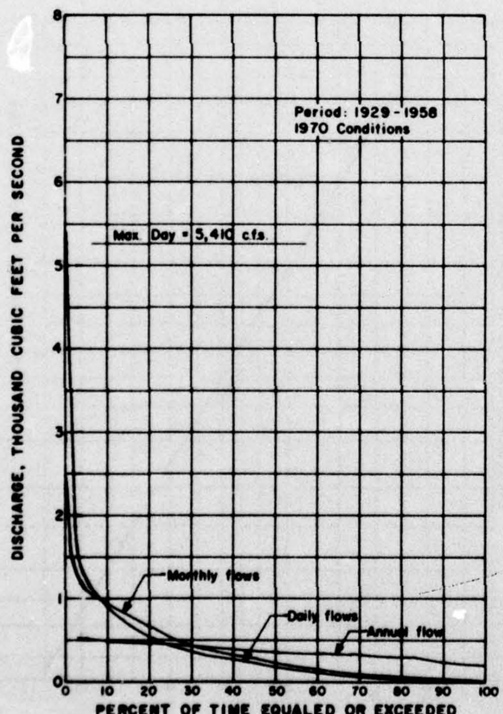


Figure 546 Duration curves, Elochoman River near Cathlamet, Washington

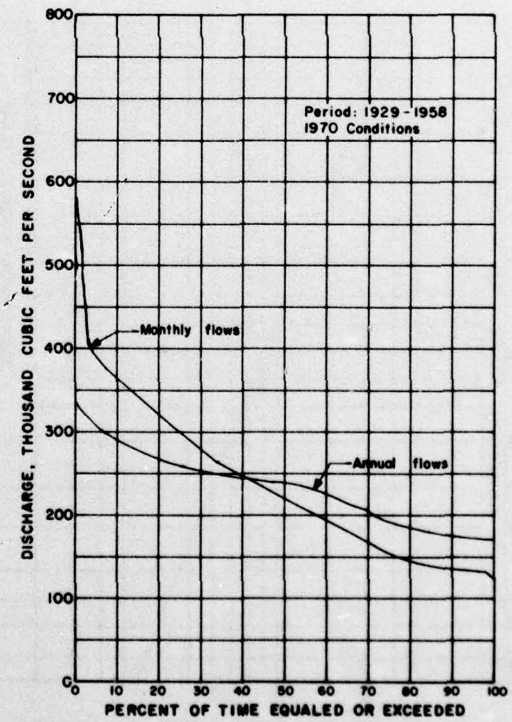


Figure 547 Duration curves, Columbia River at the Mouth, Oregon - Washington

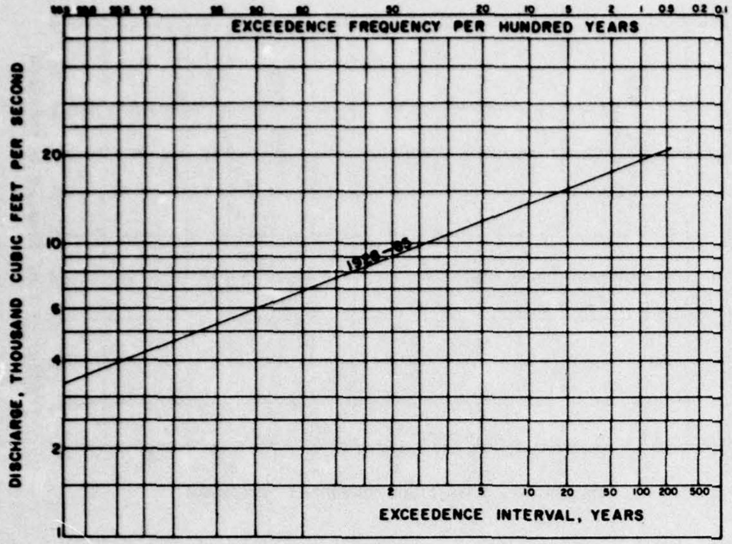


Figure 548 Frequency curve of annual peak flows, East Fork Lewis River Nr. Heisson

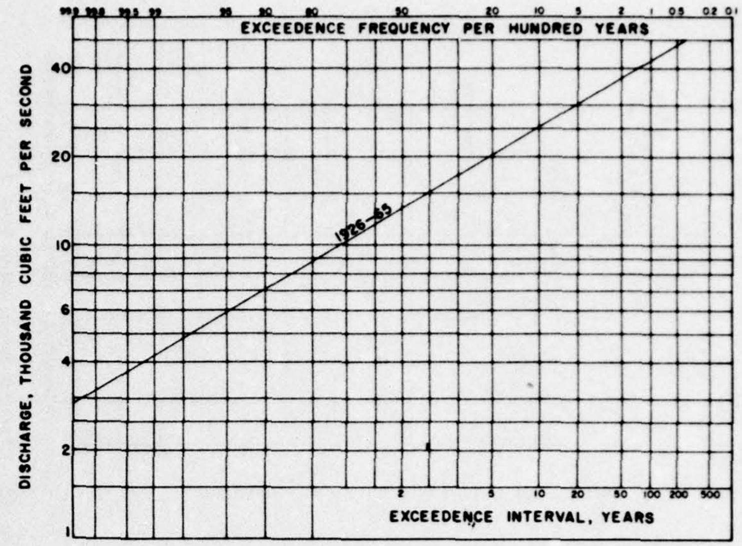


Figure 549 Frequency curve of annual peak flows, Cowlitz River at Packwood

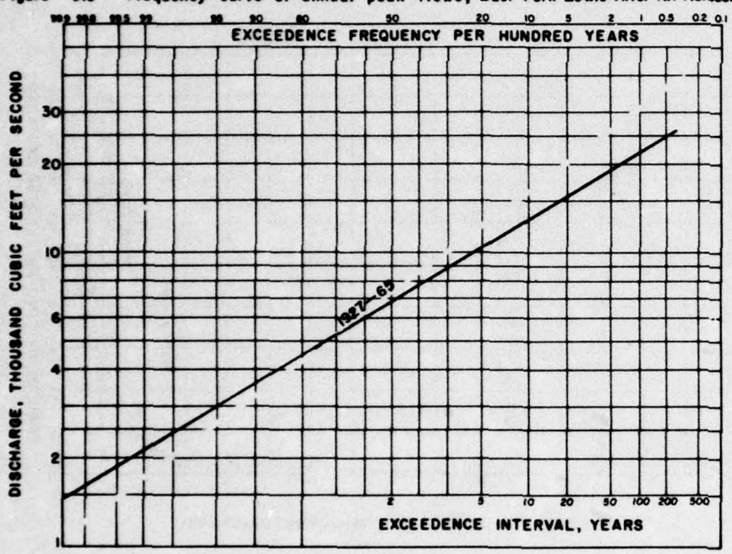


Figure 550 Frequency curve of annual peak flows, Cispus River nr Randle

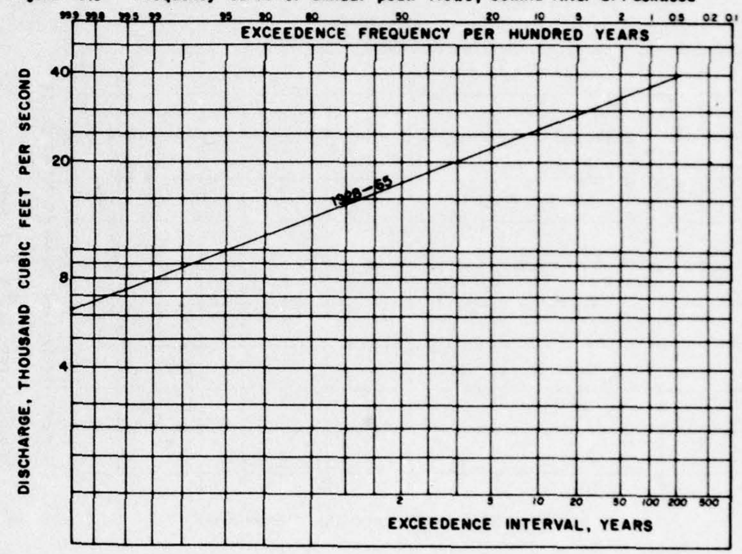


Figure 551 Frequency curve of annual peak flows, Toutle River Nr. Silver Lake

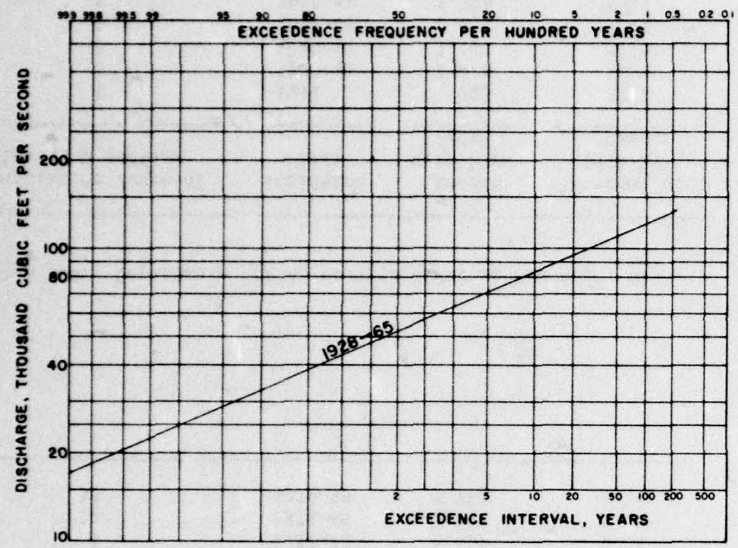


Figure 552 Frequency curve of annual peak flows, Cowlitz River at Castle Rock

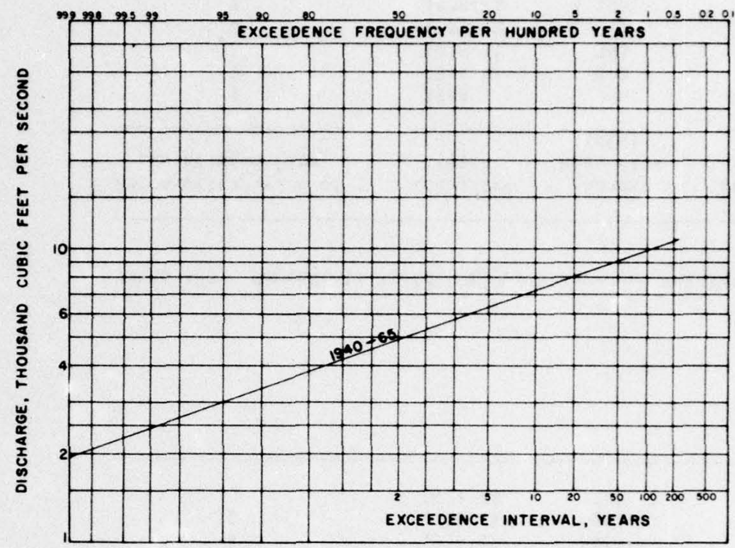


Figure 553 Frequency curve of annual peak flows, Elochoman River nr Cathlamet

Table 301. Dependable Yield, Lewis River at Ariel, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	3,090	64.8
2	1930-31	3,369	70.6
3	1929-31	3,419	71.7
3	1939-42	3,660	76.7
5	1941-45	3,781	79.2
6	1939-44	3,796	79.6
7	1939-45	3,824	80.2
8	1939-46	3,992	83.7
9	1937-45	4,029	84.4
10	1936-45	4,037	84.6
30	1929-58	4,752	100.0

Table 302. Dependable Yield, East Fork Lewis River Near Heisson

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	462	62.6
2	1930-31	510	69.1
3	1929-31	532	72.1
4	1939-42	613	83.1
5	1941-45	628	85.1
6	1939-44	630	85.4
7	1939-45	634	85.9
8	1939-46	650	88.1
9	1939-47	665	90.1
10	1936-45	661	89.6
30	1929-58	741	100.0

Table 303. Dependable Yield, Cowlitz River at Packwood, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	923	57.1
2	1940-41	1,075	66.6
3	1940-42	1,147	71.0
4	1939-42	1,216	75.2
5	1938-42	1,298	80.3
6	1937-42	1,314	81.4
7	1936-42	1,343	83.2
8	1936-43	1,383	85.6
9	1936-44	1,339	82.9
10	1936-45	1,336	82.7
30	1929-58	1,623	100.0

Table 304. Dependable Yield, Cispus River Near Randle, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent 1929-58 Mean
1	1944	766	58.6
2	1944-45	888	67.9
3	1929-31	953	72.9
4	1939-42	1,019	77.9
5	1939-43	1,107	84.6
6	1940-45	1,032	78.9
7	1939-45	1,044	79.8
8	1938-45	1,100	84.1
9	1937-45	1,111	84.9
10	1936-45	1,123	85.9
30	1929-58	1,318	100.0

Table 305 - Dependable Yield, Toutle River Near Silver Lake, Wn.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	1,182	59.8
2	1929-30	1,383	70.0
3	1929-31	1,392	70.4
4	1939-42	1,541	77.9
5	1939-43	1,621	82.0
6	1939-44	1,559	78.8
7	1939-45	1,581	80.0
8	1938-45	1,651	83.5
9	1937-45	1,666	84.3
10	1936-45	1,678	84.9
30	1929-58	1,923	100.0

Table 306 - Dependable Yield, Cowlitz River at Castle Rock

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	5,776	64.0
2	1940-41	6,097	67.6
3	1940-42	6,602	73.2
4	1939-42	6,900	76.5
5	1939-43	7,181	79.6
6	1939-44	7,017	77.8
7	1939-45	7,249	80.3
8	1938-45	7,480	82.9
9	1937-45	7,614	84.4
10	1936-45	7,669	85.0
30	1929-58	8,930	100.0

Table 307 - Dependable Yield, Elochoman River Near Cathlamet, Wn.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	219	59.6
2	1929-30	224	61.0
3	1929-31	250	68.1
4	1939-42	300	81.7
5	1939-43	317	86.4
6	1939-44	305	83.1
7	1939-45	306	83.4
8	1938-45	319	86.9
9	1937-45	284	77.4
10	1936-45	319	86.9
30	1929-58	368	100.0

Table 308 - Dependable Yield, Columbia River at the Mouth

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	165,611	69.1
2	1930-31	170,045	70.9
3	1929-31	172,742	72.1
4	1929-32	182,198	76.0
5	1929-33	202,261	84.4
6	1936-41	207,445	86.6
7	1939-45	207,165	86.4
8	1939-46	212,266	88.6
9	1937-45	210,462	87.8
10	1936-45	211,592	88.2
30	1929-58	239,677	100.0

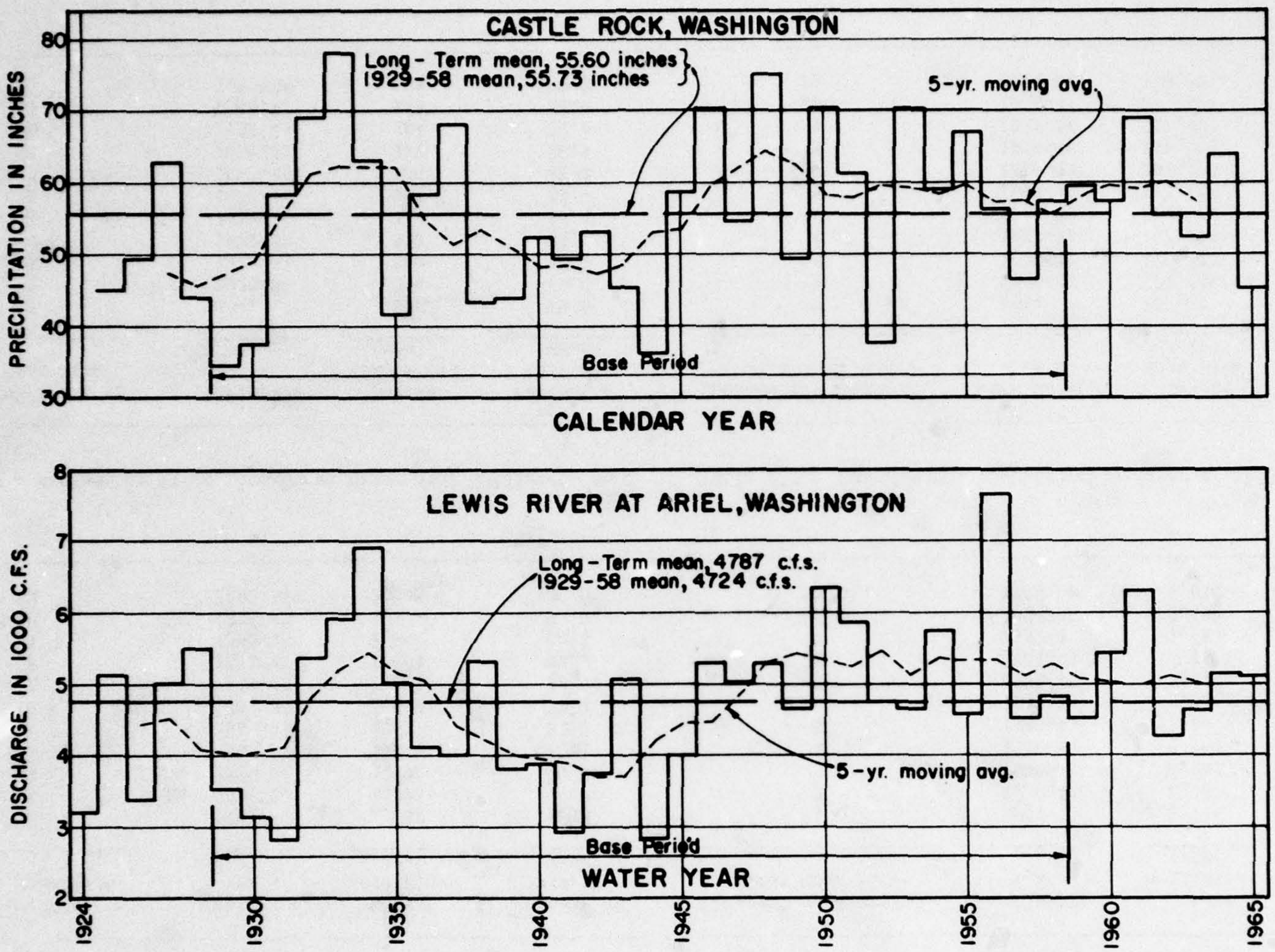


Figure 554. Long-Term Variation in Precipitation and Streamflow.

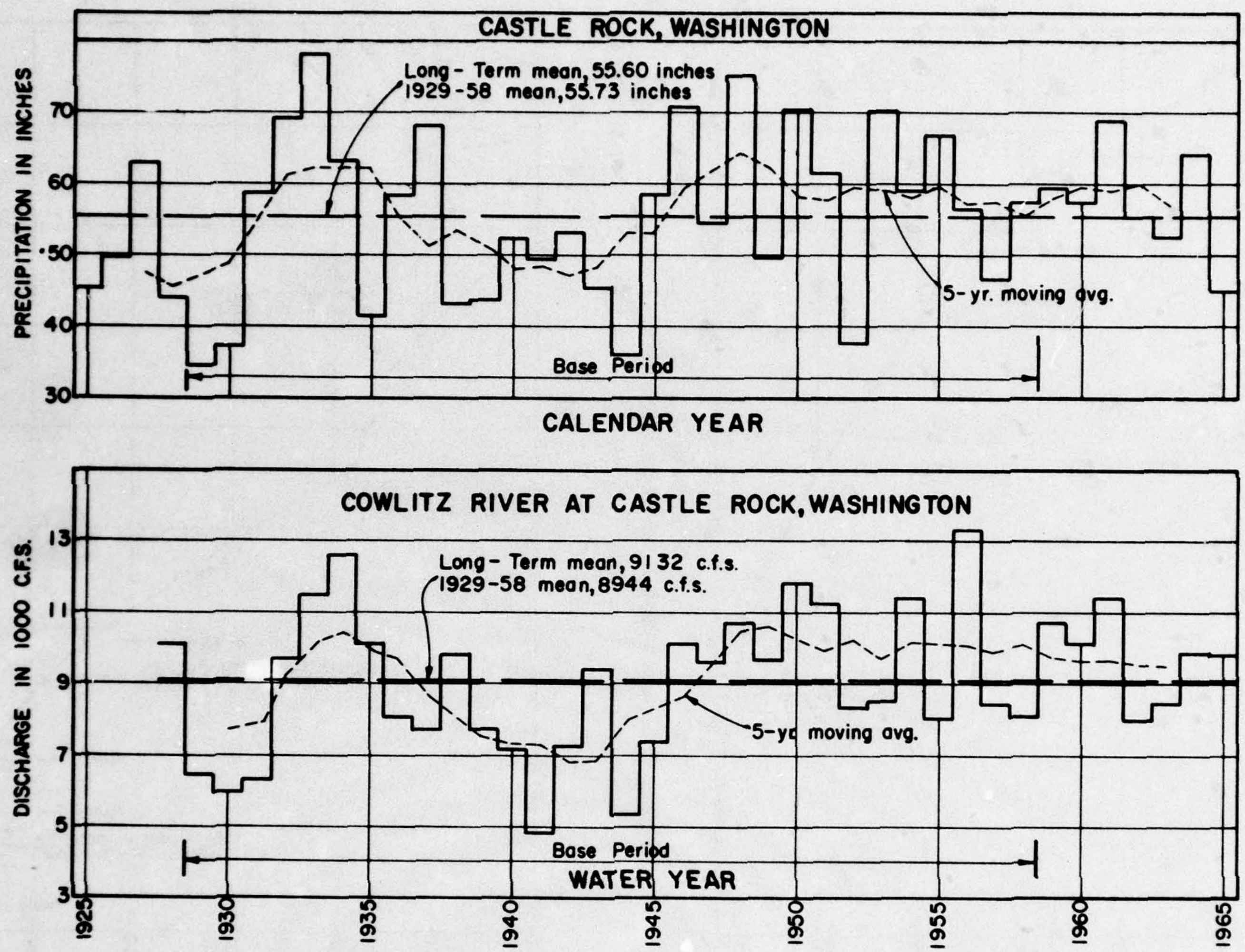


Figure 555 Long-Term Variation in Precipitation and Streamflow.

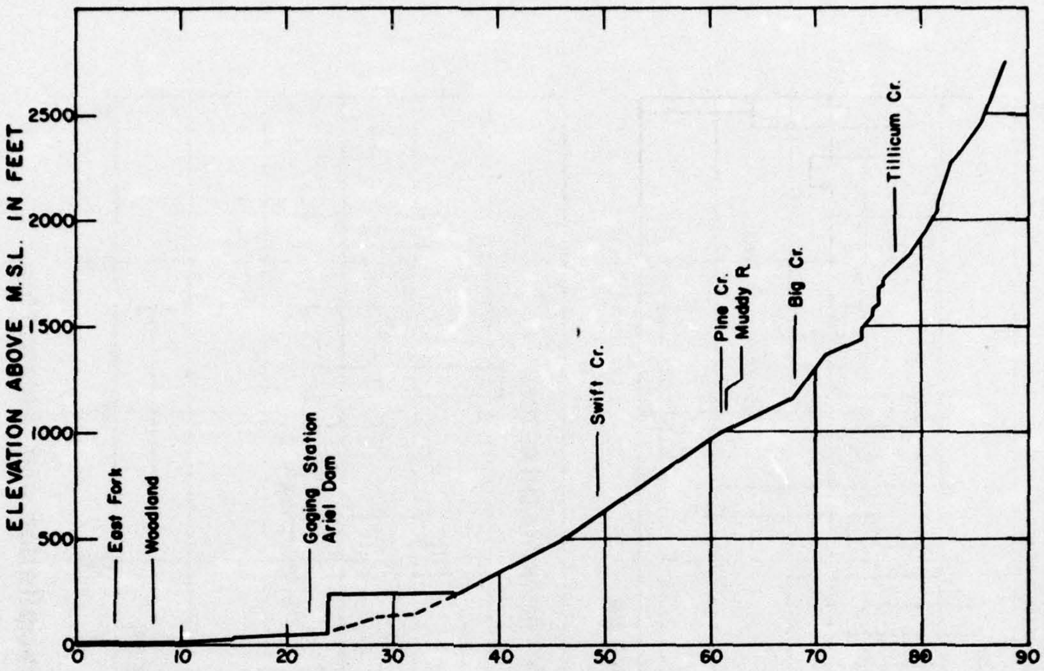


Figure 556 Stream Profile, Lewis River, Washington

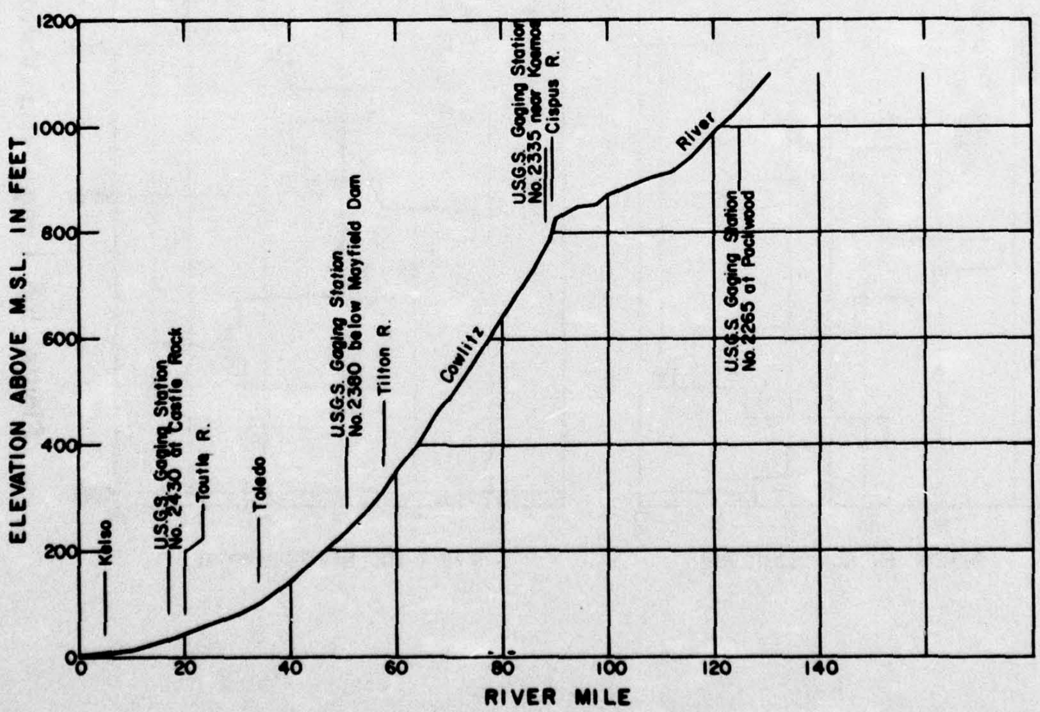


Figure 557 Stream Profile, Cowlitz River, Washington

Quality

The quality of water in Subregion 8 is generally good. Detailed data are presented on the following pages.

Chemical

The major tributaries (Cowlitz and Lewis Rivers) to the lower Columbia River below Bonneville Dam originate on the west slopes of the Cascade Mountains. Precipitation ranges from more than 100 inches in the headwater regions to about 40 inches in the lower sections. Most of the subregion is underlain by volcanic rocks which are resistant to solution. Consequently, all of the streams in the subregion contain very dilute solutes. With the exception of the Columbia River, the dissolved-solids concentration of the water of most streams averages less than 50 mg/l, and the average hardness of water is usually less than 20 mg/l. Calcium and bicarbonate are the predominant dissolved ions. Maximum dissolved-solids content is usually less than 100 mg/l. (figure 558)

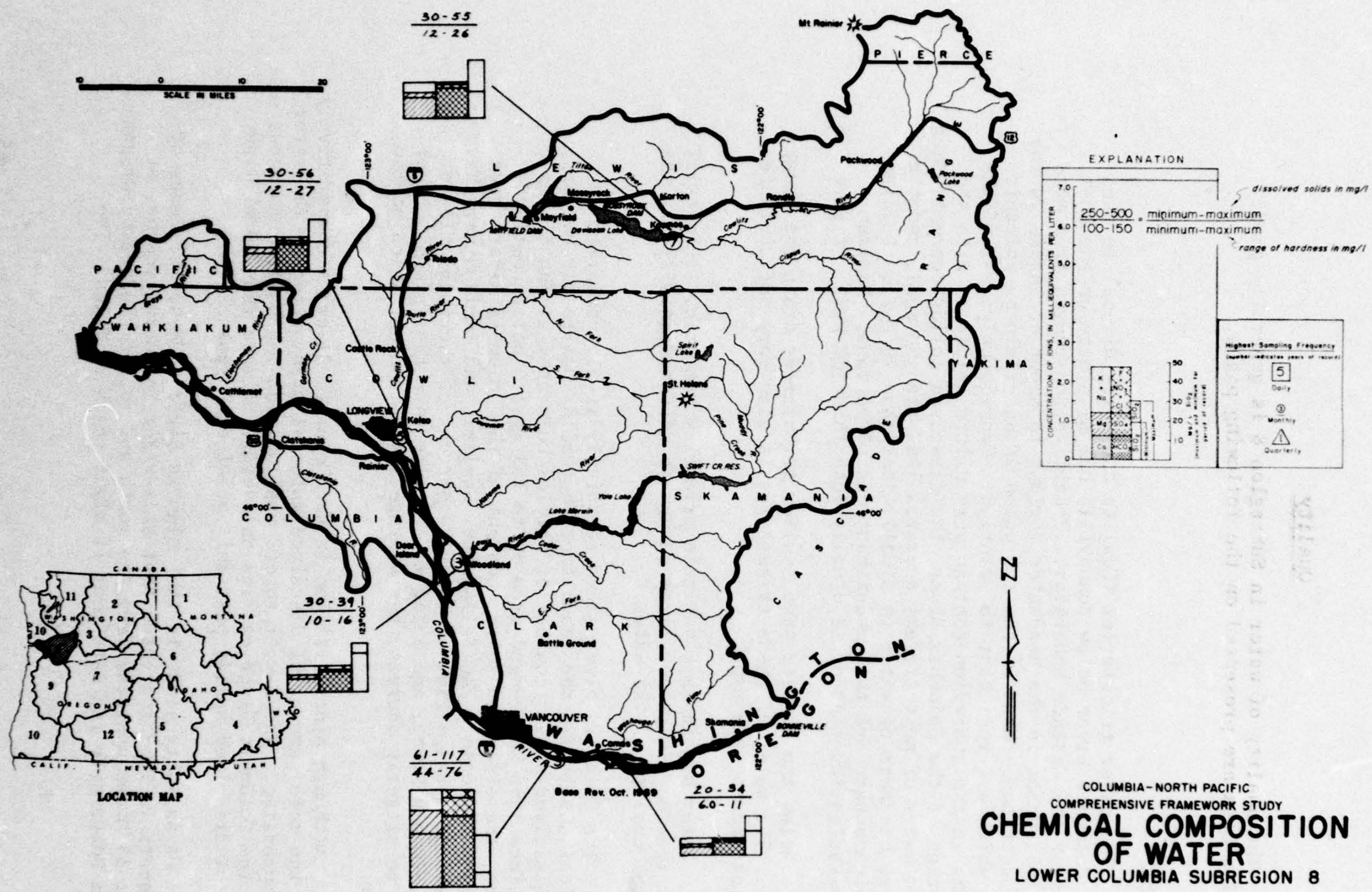
Below the Cowlitz some smaller tributaries drain the Coast Range. The water of these tributaries is also very soft, dilute calcium bicarbonate type.

Water use in this basin is primarily domestic. Industrial or irrigation use is not large enough to affect significantly the mineral quality of the water.

The Columbia River shows relatively little variation in chemical quality in the reach from The Dalles Dam to the estuary. The dissolved-solids content of samples collected at The Dalles Dam since 1958 has ranged from 69 to 163 mg/l. Below Portland, Oregon, the dissolved-solids content of the Columbia River shows a slight decrease. The Willamette, Cowlitz, and Lewis Rivers have a combined average flow of about 20 percent of the total flow of the Columbia River, and being more dilute than the Columbia River, tend to slightly decrease the average solute concentration of the river.

Although mineralization in the Columbia River is comparatively low, the total amount of dissolved material transported by the river is impressive. The 8-year record available at The Dalles Dam shows that the Columbia River carries an average of more than 20 million tons of dissolved solids past this point each year.

A salinity study in the Columbia River made by the Corps of Engineers in 1959 indicated that salt-water intrusion reaches at least 16 miles upstream from the mouth and recent studies by Oregon State University indicate that it might reach 23 miles. The



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

LOWER COLUMBIA SUBREGION 8

1968

FIGURE 558

maximum penetration of salt water was found during periods of low river flow. The partial impedance of flow due to the tides extends much farther upstream. Some effect is evident at Bonneville Dam 146 miles upstream from the ocean.

The waters in the streams of this subregion are generally of excellent mineral quality. Because many streams contain considerable turbidity at certain times of the year, some treatment would be necessary before use either as an industrial or public supply but the water is excellent for irrigation use.

Biological-Biochemical

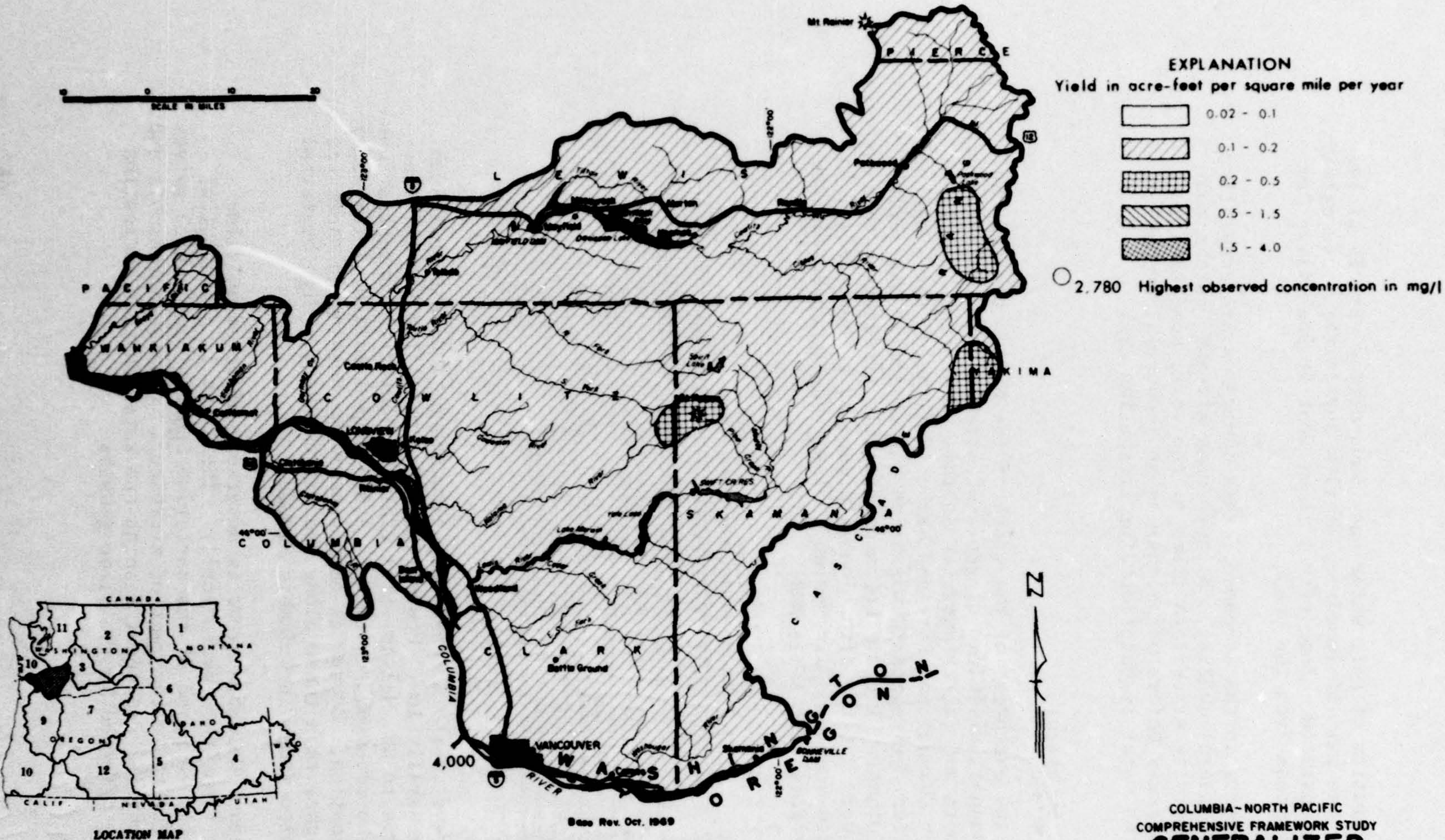
With the exception of the mouth of the Willamette and the Multnomah Channel, dissolved oxygen concentrations are satisfactory in the Columbia and its tributaries in this subregion. Levels in the Multnomah Channel and Portland harbor fall below the 5 mg/l of oxygen required for salmonoid migration during summer and early fall. The Columbia River is not significantly affected by this inflow, however, and the situation is presented in more detail in the Willamette Subregion discussion. Dissolved oxygen levels are shown in the following table 309.

Table 309. Dissolved Oxygen & Coliform Organisms Densities, Lower Columbia Subregion

Location	Dissolved Oxygen mg/l			Coliform Organisms MPN/100 ml		
	Mean	Min	Max	Mean	Min	Max
Lewis R. at Ariel	10.8	8.3	12.4	3	0	36
Lewis R. at Woodland	11.1	9.0	13.8	177	0	930
Kalama R. at Kalama	11.2	8.2	13.2	723	0	11,000
Cowlitz R. nr. Toledo	11.4	8.8	15.1	134	0	930
Cowlitz R. nr. Kosmos	11.4	9.2	13.6	67	0	360
Toutle R. nr. Castle Rock	11.2	8.8	13.2	112	0	750
Cowlitz R. at Kelso	10.9	8.0	14.4	178	0	930
Coweeman R. at Kelso	10.6	5.6	13.8	1,819	0	24,000
Columbia R. at Beaver Terminal	10.8	8.1	13.5	3,257	0	24,000

Observed coliform densities, also shown, indicate that such levels are generally low. However, the Columbia from the Portland-Vancouver area to St. Helens still exhibits bacterial concentrations well above the recommended limit of 1,000 organisms/100 ml for water-contact recreation. Bacterial counts near the Washington shore are generally higher than those along the Oregon shore. High bacterial levels are also found in Columbia Slough.

The lower Columbia River is adversely affected by slime growth which flourishes periodically. The slime is a biological mass, primarily composed of the bacterium Sphaerotilus, which serves as a matrix for the attachment of microscopic plants and animals and debris. Commercial and sport fishing and water-contact recreation are adversely affected by the slime growths.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

LOWER COLUMBIA SUBREGION 8

1968

FIGURE 559

Sediment

The only suspended-sediment concentration data available in the subregion are from a few samples on the Cowlitz and East Fork Lewis Rivers collected in 1951 (unpublished data) and on the Columbia River at Vancouver, Washington, collected in 1951-52 and since 1962. Sediment discharge during 1962-63 was described by Haushild and others (1966) in relation to transport of radionuclides. Concentrations generally were very low, ranging from 1 to 50 mg/l, except during short periods of discharge from storm runoff and spring snowmelt. A storm in February 1963 produced a sediment concentration of 570 mg/l in the Columbia River at Vancouver. The December 1964 flood produced 4,000 mg/l.

Only during storm and snowmelt periods is there enough sediment in the Columbia River water to allow determination of particle-size distribution. During 1963, the estimated particle-size composition of the total sediment discharge at Vancouver was 35 percent sand, 50 percent silt, and 15 percent clay.

Figure 559 shows sediment yields (30) ranging from 0.1 to 0.5 acre-foot per square mile per year. The only two small areas shown to exceed a yield of 0.2 acre-foot per square mile per year are on Mount St. Helens and Mount Adams. The major sources of sediment are the sloping agricultural and forested lands with the agricultural lands contributing about three times as much sediment per square mile as the forested lands.

Water Temperature

Sufficient water temperature data for graph construction are lacking. However, inspection of graphs for Subregions 7 and 9 will provide some idea of probable temperatures.

GROUND WATER

The alluvial deposits of Quaternary and late Tertiary age (QTal) constitute the most important aquifers. Moderate to large yields of water are obtained at many places, and the deposits are capable of sustaining a much larger development. The other aquifer units are important as sources of supply locally, or are important in the streamflow regimen.

Except for some moderately to highly saline water from marine sedimentary strata, the water is of good to excellent quality.

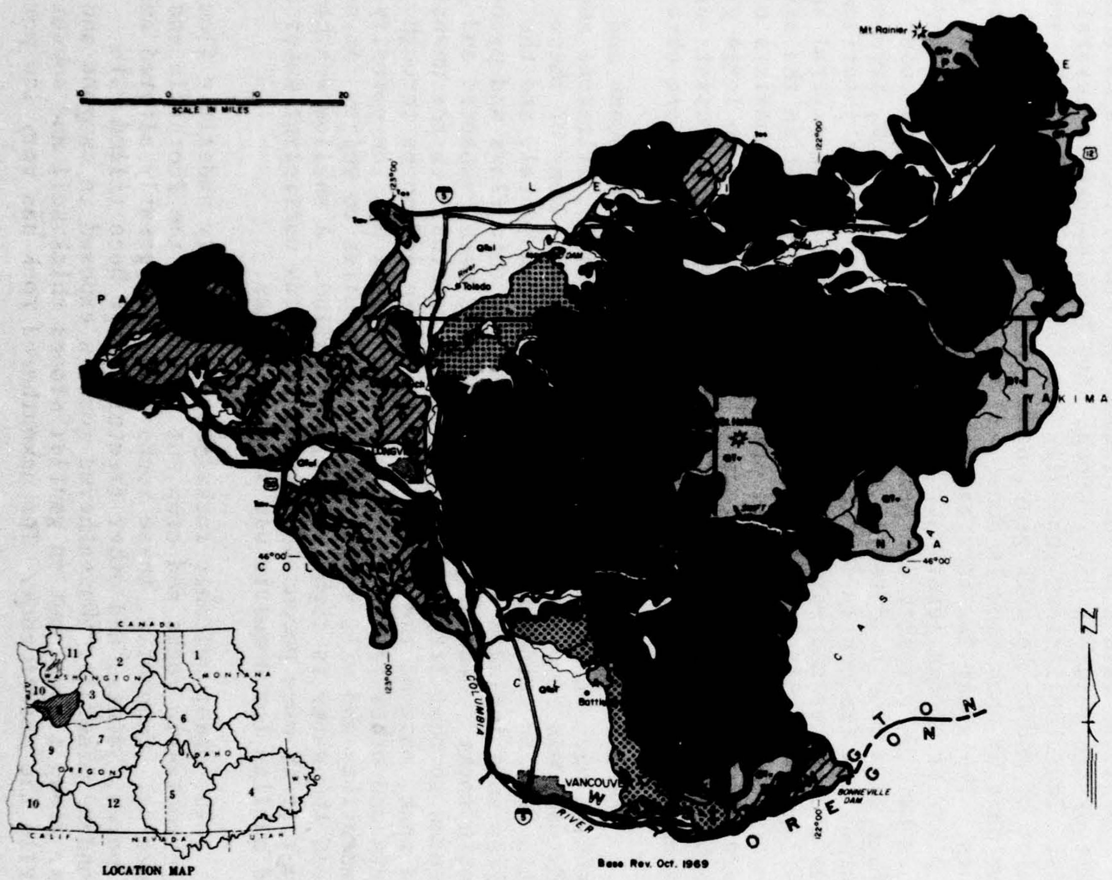
Several reports describe aquifers and occurrence of ground water in Subregion 8. (40, 82, 200)

Aquifer Units and Their Hydrologic Characteristics

Five aquifer units have been delineated in Subregion 8, but only one, the alluvial deposits (QTal), is of major importance as a source of ground water. Aquifer units are shown on the map, figure 560, which is based primarily on the geologic map of Washington (54).

The alluvial deposits (QTal) form extensive benches and terraces in western Clark and southern Lewis Counties. Narrower terraces occur elsewhere along the Lewis, Cowlitz, and Columbia Rivers. In western Clark County the unit includes alluvium of Holocene age, glaciofluvial deltaic deposits of late Pleistocene age, and the upper Troutdale deposits of late Pliocene or early Pleistocene age. In Lewis County the unit includes Holocene alluvium, glaciofluvial outwash of late Pleistocene age, and older alluvial deposits resembling the upper Troutdale (Logan Hill Formation) that are considered to be of early Pleistocene age (128). The alluvial deposits consist predominantly of sand and gravel and, where as much as a few tens of feet of clean sand and gravel are saturated, will yield large to very large supplies of water. Yields up to 4,600 gpm with only a few feet of drawdown have been reported. (82-85) However, near the western edge of Clark County, and at a few other places, the deposits are mostly fine sand and silt, and yields are much smaller.

Volcanic rocks of Quaternary and late Tertiary age (QTv) also are porous and very permeable, but except for a few small occurrences, are found only in high uninhabited areas of the Cascade Range. In those areas they serve as ground-water storage reservoirs and the streams draining them have high base flows. A few domestic wells have moderate yields with small drawdowns. One well drilled for irrigation use near Battleground was reported to yield 420 gpm with 36 feet of drawdown. (82-166)



EXPLANATION

QTal

Alluvial and glacial deposits of Quaternary age.

Yields moderate to large supplies from clean sand and gravel. Quantity is related to saturated thickness.

Dissolved solids generally < 300 mg/l. Water soft to hard. Some excessive iron.

QTv

Volcanic lavas and pyroclastics of Quaternary late Tertiary age.

Porous and highly permeable, important reservoir in headwaters of some streams. Yields moderate to large supplies to wells.

Dissolved solids < 150 mg/l; no hazardous constituents.

Tos

Older consolidated sedimentary strata; Eocene to Oligocene age.

Generally low porosity and permeability, and yields only small amounts of water.

Shallow water generally good quality; deeper water may be highly saline.

Sedimentary rocks of Pliocene, late Miocene age.

Thin layers of lightly cemented sand and gravel yield small to moderate amounts of water.

Shallow water generally has low dissolved solids; deeper water may be saline.

Tmv

Volcanic rocks of Miocene age.

Small yields obtained from single flows; moderate to moderately large yields where several interflow zones are penetrated.

Dissolved solids < 150 mg/l. Water generally soft, occasionally moderately hard.

Older volcanic flows and pyroclastics; Eocene to Oligocene age.

Generally low porosity and permeability; small yields, adequate for domestic use.

Probably dissolved solids generally low. Water at some places highly mineralized.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

AQUIFER UNITS

LOWER COLUMBIA SUBREGION 8

1968

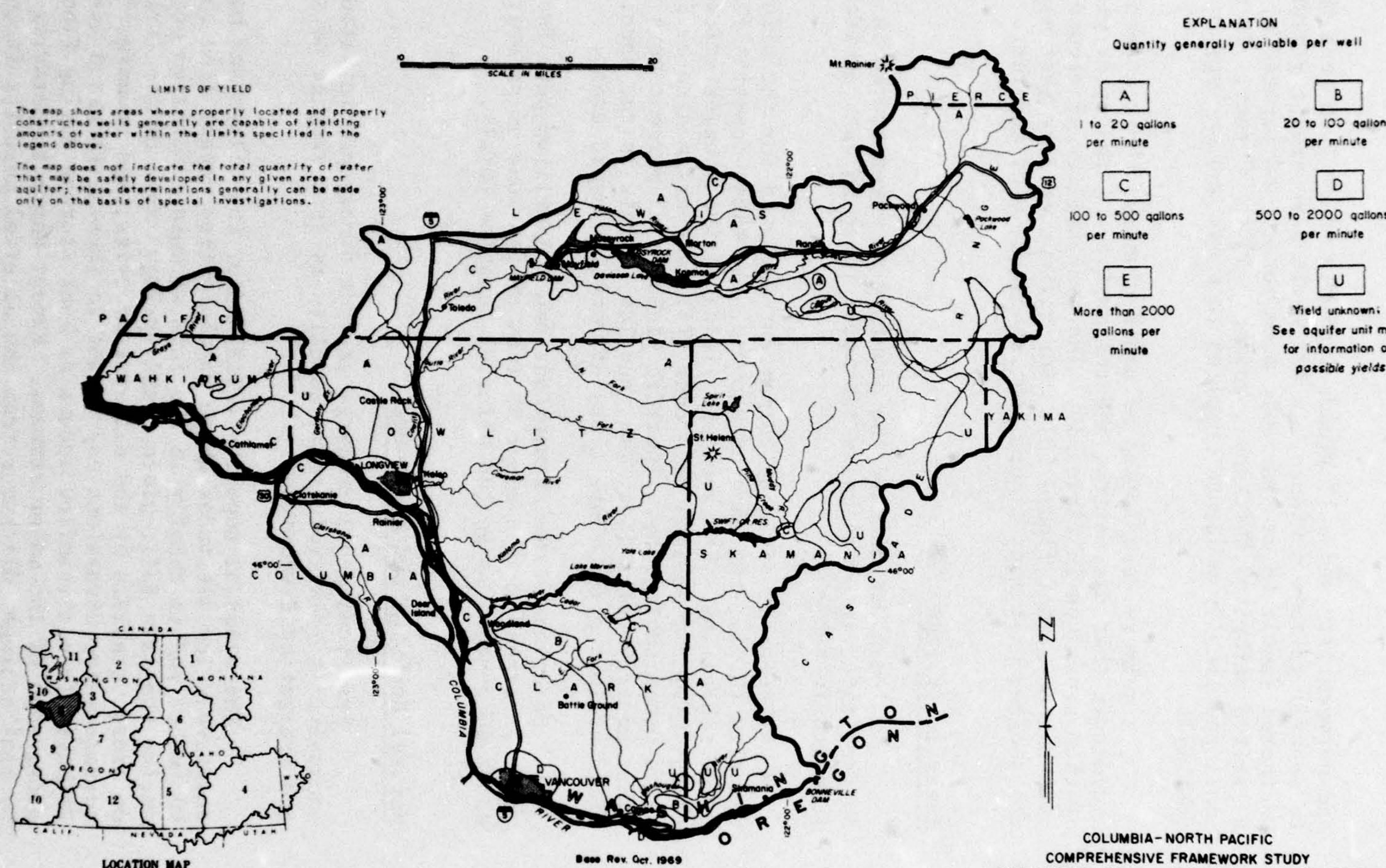
FIGURE 560

The younger Tertiary sedimentary rocks (Ts) include the nonmarine sedimentary rocks of Miocene and Pliocene(?) age in west-central Lewis County (200-25 to 27), the Wilkes Formation of upper Miocene and lower Pliocene(?) age (128-34 to 37), and the lower member of the Troutdale Formation of Pliocene age (82-23 to 39). The deposits consist chiefly of fine-grained materials: clay, claystone, silt, siltstone, and very fine, lightly to moderately cemented sand. However, a few thin layers of permeable coarse sand or sand and gravel are interbedded in the finer materials at some places. These coarser beds are capable of supplying moderate yields.

Basaltic lava flows of Miocene age (Tmv), correlated with basalt of the Columbia River Group, have been mapped in several areas. Individual flows generally are 25 to 100 feet thick, and consist of medium to dark gray, dense to vesicular basalt. The major part of each flow is dense and has only a few widely spaced joints. The upper few feet of each flow commonly is vesicular and has platy or blocky jointing. A single flow overlain by sedimentary strata has low porosity and permeability, but, where the upper surface of a flow is directly overlain by a second flow, irregular openings are frequently left between the flows. These interflow zones are porous and permeable, and wells penetrating several interflow zones have moderate to large yields. The basalt in the extensive area of this aquifer unit northwest of Longview consists of several flows, and three or four wells with moderate to large yields have been drilled in this area. Elsewhere, the unit consists of only one or two flows, and generally only small yields are obtained.

The consolidated sedimentary rocks (Tos), of Eocene and Oligocene age, include marine and nonmarine shale, siltstone and sandstone, and some conglomerate and coal beds. Many of these strata contain tuffaceous and other volcanic material, and the aquifer unit includes some intercalated volcanic flows and pyroclastic rocks. Generally those strata have been compacted and cemented so that little primary porosity remains. In the unweathered rock, most of the water is contained in and moves through joints and other fractures. Usually this unit has low porosity and permeability and will yield only small supplies to wells. At some places the water is lightly to highly saline. A shallow weathered zone that is more porous and permeable yields sufficient water of good quality for domestic use at many places.

The older volcanic rocks (Tov) are mainly andesitic flows and pyroclastic rocks and crop out chiefly in the foothills and mountains. Generally, these rocks have been greatly altered and the pores, joints, and other fractures have been filled with secondary minerals. Unweathered rock is exposed in canyons and on other steep slopes, but on gentler slopes thick soil and subsoil overlie the parent rock. The unweathered rock has very low porosity



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER

LOWER COLUMBIA SUBREGION 8

1968

FIGURE 561

and permeability and well yields commonly range from less than one to several gallons a minute. A few wells have higher yields. The weathered mantle is considerably more porous and permeable, but has a limited saturated thickness, commonly 30 to 50 feet. It yields small and locally moderate supplies to wells and springs in the foothills.

A summary description of aquifer units, their general hydrologic characteristics, and the quality of the water yielded by them are given in table 310. The availability of ground water is shown on a map, figure 561. For maximum utility that map and the aquifer unit map, figure 560, should be used together.

Water in Storage

A rough estimate of the quantity of water stored in a 50-foot thick interval below the water table in each aquifer unit is given in table 311.

A specific yield of 20 percent was used for the alluvial deposits (QTal), the same as was used for those deposits (Qal) in other subregions. The specific yields of the younger volcanic rocks (QTv) and sedimentary rocks (Ts) were assumed to be 5 percent, as in other subregions. Specific yields of 2 percent were used for other aquifer units (Tos, Tmv, and Tov). This is the specific yield estimated for those types of rocks in humid areas.

Using the above assumptions about 8 million acre-feet of water is stored in the upper 50 feet of the zone of saturation. About 60 percent is in the alluvial deposits (QTal).

Natural Recharge and Discharge

Practically all recharge is from direct precipitation and snowmelt. A relatively small quantity is from seepage of streamflow and irrigation diversions.

The alluvial deposits (QTal) occur in valleys and basins, at relatively low altitudes where precipitation ranges from about 45 to 60 inches and is chiefly in the form of rain. Recharge occurs mostly during the late fall, winter, and spring. Most of the irrigation is on areas underlain by the alluvial deposits, and recharge from surface-water diversions may amount to several thousand acre-feet. Recharge from streamflow occurs as bank storage during flood stages along some of the major streams. Except where temporarily blocked by bank storage, discharge from the alluvial deposits is continuous. Hydrographs illustrating the response of water levels to recharge and discharge are shown in figure 562. Average annual recharge to

Table 310. Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 8

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
QTal: Alluvial and glacial deposits, some lake deposits. Includes upper part of Troutdale Fm. at some places. Chiefly Pleistocene and Holocene in age; may include some late Pliocene alluvium.	Unconsolidated to lightly cemented gravel, sand, and silt deposited in stream channels and flood plains, and as deltas and alluvial fans, at many places now occurring as benches and terraces. Includes some lacustrine silt and clay deposits.	Clean, unweathered sand and gravel moderately to extremely permeable, will yield 100 to more than 1,000 gpm where 10 to 50 ft or more of material is saturated. Weathered, cemented strata yield much less.	Total solids rarely more than 300 mg/l. Water generally soft, at places moderately hard to hard. Excessive iron common.
QTv: Volcanic rocks of late Pliocene, Pleistocene, and Holocene age. Includes Boring Lava, Quaternary volcanics of Mount St. Helens, Mount Adams.	Light to dark gray, finely vesiculated, open-textured basalt, and pyroclastic rocks, including red scoria, cinders, and ash. May include some andesite flows.	Moderately to highly porous and permeable. Few wells utilize aquifer because of limited extent in populated areas. Important reservoir rock on flanks of Mount St. Helens, Mount Adams, stabilizing discharges of streams draining those areas.	Dissolved solids less than 150 mg/l; water moderately hard.
Ts: Sedimentary rocks, chiefly fluvial and lacustrine, of Pliocene and late Miocene age.	Chiefly thin to massive bedded clay, claystone, silt, siltstone, and lightly to well cemented sand and gravel.	Thin layers of lightly cemented sand and gravel yield small to moderate quantities of water.	Dissolved solids range from low to very high. Shallow water usually is of good quality. Deeper water may be saline.
Tmv: Volcanic rocks of Miocene age; includes basalt of Columbia River Group and similar lavas.	Medium to dark gray, dense to vesicular basalt, frequently with well-developed columnar jointing. Lower parts of flows usually dense, massive; upper parts vesicular, with platy or blocky jointing.	Bottom and central part of flow relatively impermeable. Upper few feet of some flows and openings between successive flows comprise permeable interflow zones. Wells have moderate to moderately large yields where several interflow zones penetrated.	Dissolved solids generally less than 150 mg/l. Water soft to moderately hard.
Tos: Consolidated sedimentary rocks, marine an nonmarine, of Eocene and Oligocene age.	Massive to thin-bedded consolidated sandstone, siltstone, shale; some conglomerate and coal beds. Many beds are partly or largely of tuffaceous or other volcanic rock material.	Low porosity and permeability. Wells yield less than one to a few tens of gallons per minute; generally are adequate for domestic supply. Base flow of streams draining unit usually is low.	Water quality ranges from good to unusable. Shallow wells usually have good-quality water; deeper wells more saline water.
Tov: Volcanic rocks of Eocene and Oligocene age; includes Goble Volcanics and Keechelus andesitic rocks.	Chiefly andesite flows and flow breccia; bedded andesite breccia with interbedded basalt and andesite; pyroclastic rocks and mudflows; some sedimentary interbeds.	Generally low porosity and permeability. Well yields usually are a few to a few tens of gallons per minute. Upper weathered zone serves as a shallow aquifer for domestic wells and to maintain base flow of streams.	No data available. Probably low to moderate dissolved solids except where contaminated by water from adjacent marine strata.

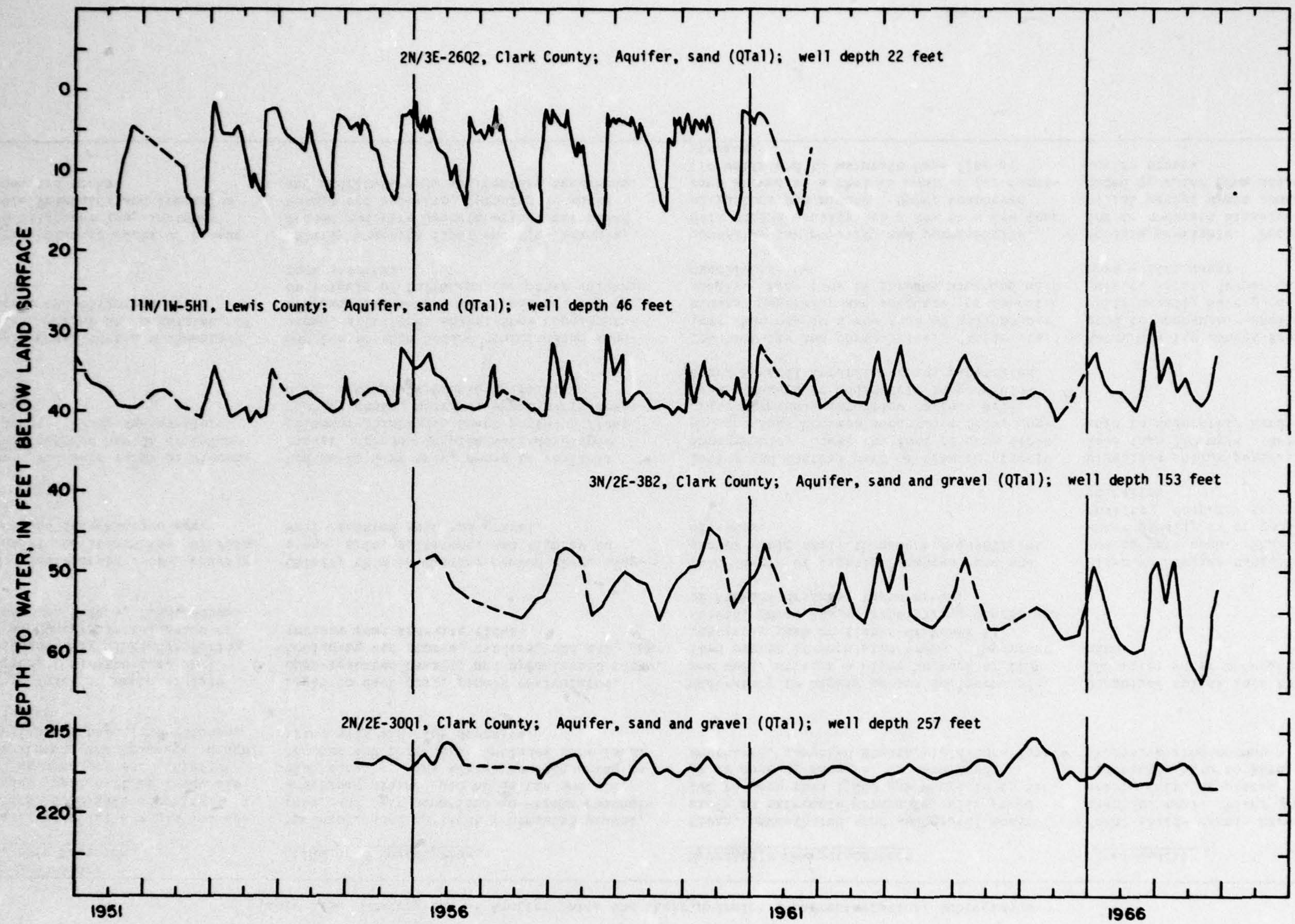


Figure 562 Hydrographs of selected wells in subregion 8

and discharge from the alluvial deposits is estimated to be equivalent to 30 inches over the area of outcrop.

The younger volcanic rocks (QTv) occur only at high altitudes, where annual precipitation ranges from 70 to 140 inches, much of it as snow. Recharge probably is largely from fall rains and spring snowmelt. The rocks are so porous and permeable that most of the precipitation becomes recharge. Average annual recharge to and discharge from the aquifer unit was estimated to be equivalent to 50 inches over the area.

The other aquifer units (Ts, Tos, Tmv, and Tov) crop out generally at altitudes ranging from about 500 to 5,000 feet. Recharge is chiefly from rainfall at lower altitudes, but spring snowmelt is important at higher altitudes. Stream hydrographs and flow-duration curves indicate that ground water supplies a component of discharge to streams equivalent to about 15 to 30 inches over the area annually. A value of 20 inches was used for estimating average annual recharge to and discharge from these units.

The estimates of average annual natural recharge and discharge are given in table 311. The total annual recharge and discharge is estimated to be about 6 million acre-feet, more than 50 percent from the older volcanic rocks (Tov). Only about 20 percent is from the alluvial deposits (Qal). About 16 percent is from the younger volcanic rocks (QTv) which supply large base flows to the Cispus, Toutle, Kalama, and Lewis Rivers.

Table 311. Storage, Recharge, and Discharge of Ground Water in Aquifer Units in Subregion 8

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge	
	Sq. Mi.	Acres (1000's)	Specific Yield (percent)	Depth Used (ft)	Water (1000's ac-ft)	Inches Over Area	(1000's ac-ft)
QTal	763	490	20	50	4,900	30	1,200
QTv	397	254	5	50	650	50	1,000
Ts	220	140	5	50	350	20	230
Tos	320	205	2	50	205	20	340
Tmv	320	200	2	50	200	20	330
Tov	3,000	1,900	2	50	1,900	20	3,200
TOTAL (rounded)	5,000				8,000		6,300

Annual Ground-Water Withdrawal

Ground-water withdrawal (table 312), almost entirely from pumped wells, is about 140 thousand acre-feet a year. This is less

Table 312 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 8, 1970

	Oregon	Washington	Total
	Ac-ft per year; all quantities in thousands		
Irrigation			
Acres irrigated	0.1	5.0	5.1
Withdrawal	.3	8.0	8.3
Consumptive use	.1	5.0	5.1
Industrial 1/			
Withdrawal	2.0	110.0	112.0
Consumptive use 2/	.1	5.5	5.6
Public Supplies			
Persons served	3.0	92.0	95.0
Withdrawal	.6	16.0	17.0
Consumptive use 3/	.1	3.2	3.3
Rural-Domestic			
Persons served	8.0	50.0	58.0
Withdrawal 4/	.9	5.6	6.5
Consumptive use 5/	.4	2.8	3.2
Stock			
Withdrawal and consumptive use 6/	.15	.94	1.1
TOTAL WITHDRAWAL (rounded)			140.0
TOTAL CONSUMPTIVE USE (rounded)			18.0

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

than 2 percent of the natural recharge and discharge. Most of the withdrawal is from the alluvial deposits (QTal).

Chemical Quality of Water

The water in Subregion 8 is of good to excellent quality for most uses. The concentration of dissolved solids usually is less than 300 mg/l, except that some water from marine sedimentary rocks may be brackish. The water is chiefly of the calcium magnesium bicarbonate type and generally is soft or only moderately hard. Excessive iron is a common problem, and except for hardness, generally is the only water quality problem encountered.

Present Use and Future Availability

Estimates (projected to 1970) of ground-water withdrawal and consumptive use are given in table 312. Most of the water is withdrawn for industrial use or public supply--largely nonconsumptive uses. Total annual consumptive use, therefore, is only about 18,000 acre-feet. Most water not used consumptively is discharged into the Columbia River; only a small part returns to the aquifers. However, because some of the water withdrawn by pumping is induced recharge from the Columbia River, net ground-water withdrawal may not be more than 50,000 to 60,000 acre-feet a year. Most of the withdrawal is from the alluvial deposits and amounts to about 5 percent of the natural discharge from those aquifers.

Moderately large to very large yields can be obtained from the alluvial deposits (QTal) at many places in Clark, Cowlitz, and Lewis Counties. Under present conditions, considerable recharge is rejected during late winter and spring; increased pumpage would be balanced, in part, by an increase in recharge. Many of the larger wells are drilled near the Columbia River and other large streams, and much of their withdrawal is supplied by induced infiltration from those rivers. It has been estimated that along favorable reaches of the Columbia River, yields of about 50 to 100 mgd might be obtained per mile length. (82-93)

The Miocene basalt (Tmv) is capable of moderately large to large yields where several interflow zones are encountered. The largest area of basalt, consisting of several successive flows, is northwest of Longview. Several large-yield wells have been drilled there and the basalt aquifers in that area probably would support considerable additional development. Elsewhere, the basalt is only one or two flows thick and yields are small to moderate.

Artificial Recharge

There is no artificial recharge of aquifers. However, water pumped from wells and used in heat-exchange installations is returned to the aquifer through recharge wells at several places in Clark County. Artificial recharge does not appear needed.

Water Rights

Oregon

The part of Subregion 8 in Oregon consists of drainage basins to the Columbia River, downstream from St. Helens to just beyond the mouth of the Clatskanie River. It is the eastern part of the Tillamook subbasin of the North Coast Basin as defined by the Oregon Water Resources Board. Primary water rights for seven wells were on file with the State Engineer's Office as of March 1967. Prime rights allow withdrawal of 4,122 acre-feet a year, of which 3,760 acre-feet is for municipal use and the remainder is for irrigation. The maximum rate of withdrawal is about 7 cfs (3,200 gpm), during the irrigation season. Data on supplemental water rights are not available. Ground-water rights are summarized by major-use category in table 313.

Table 313 - Summary of Ground-Water Rights, Oregon Part of Subregion 8, 1967

Basin No.	Basin Name	Number of Wells	Domestic (ac-ft)	Municipal (ac-ft)	Industrial (ac-ft)	Irrigation Acres	Irrigation (ac-ft)	Other (ac-ft)	Total (ac-ft)
1	North Coast (part)	7	0	3,760	0	145	362	0	4,122

Washington

In that part of Subregion 8 located in the State of Washington, essentially Water Resource Inventory Areas 25 through 28 (figure 521), a total of 515 active ground-water right appropriation and declaration records, in permit and certificate stages, were on file with the Department of Water Resources on September 30, 1966. Prime rights in this area allow summer period withdrawals totaling 186,130 gpm (415 cfs) of which 185,030 gpm has a consumptive effect on the resource and 1,100 gpm is classified as being partly consumptive. Only 80 gpm has been appropriated under supplemental rights.

Prime water-right quantities for the more important use categories and total actual ground-water right quantities are listed in table 314 according to Water Resource Inventory Areas

as defined by the State of Washington, Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 314 - Summary of Ground-Water Rights, Washington Part of Subregion 8, 1966

Basin No.1/	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total2/
				(Gallons per Minute)				
25	Cathlamet Area		495	2,438	7,480	3,100	-	10,083
26	Cowlitz	445	9,664	5,020	300	1,500	765	13,622
27	Kalama-Lewis	1,350	9,605	2,800	1,145	-	160	12,381
28	Vancouver Area	18,828	34,676	34,377	85,727	-	1,626	150,044
TOTAL		20,623	54,440	44,635	94,652	4,600	2,551	186,130

1/ Water Resource Inventory Area number as shown in figure 521.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

Ground water is nearly everywhere effluent to the streams. Discharge of ground water is continuous throughout the year, except for short periods along some reaches of large rivers where flood-flows may put water into temporary storage in the alluvium of the flood plain adjacent to the river.

The ground-water component of the average discharge of streams ranges from about 15 percent in streams draining terrain underlain by the older volcanic rocks (Tov) and sedimentary rocks (Tos) to more than 50 percent for streams draining the younger volcanic rocks (QTv). However, the younger volcanic rocks underlie a comparatively small part of the subregion and no large stream drains those rocks exclusively.

Hydrographs, figure 563, show the low-flow characteristics of selected streams.

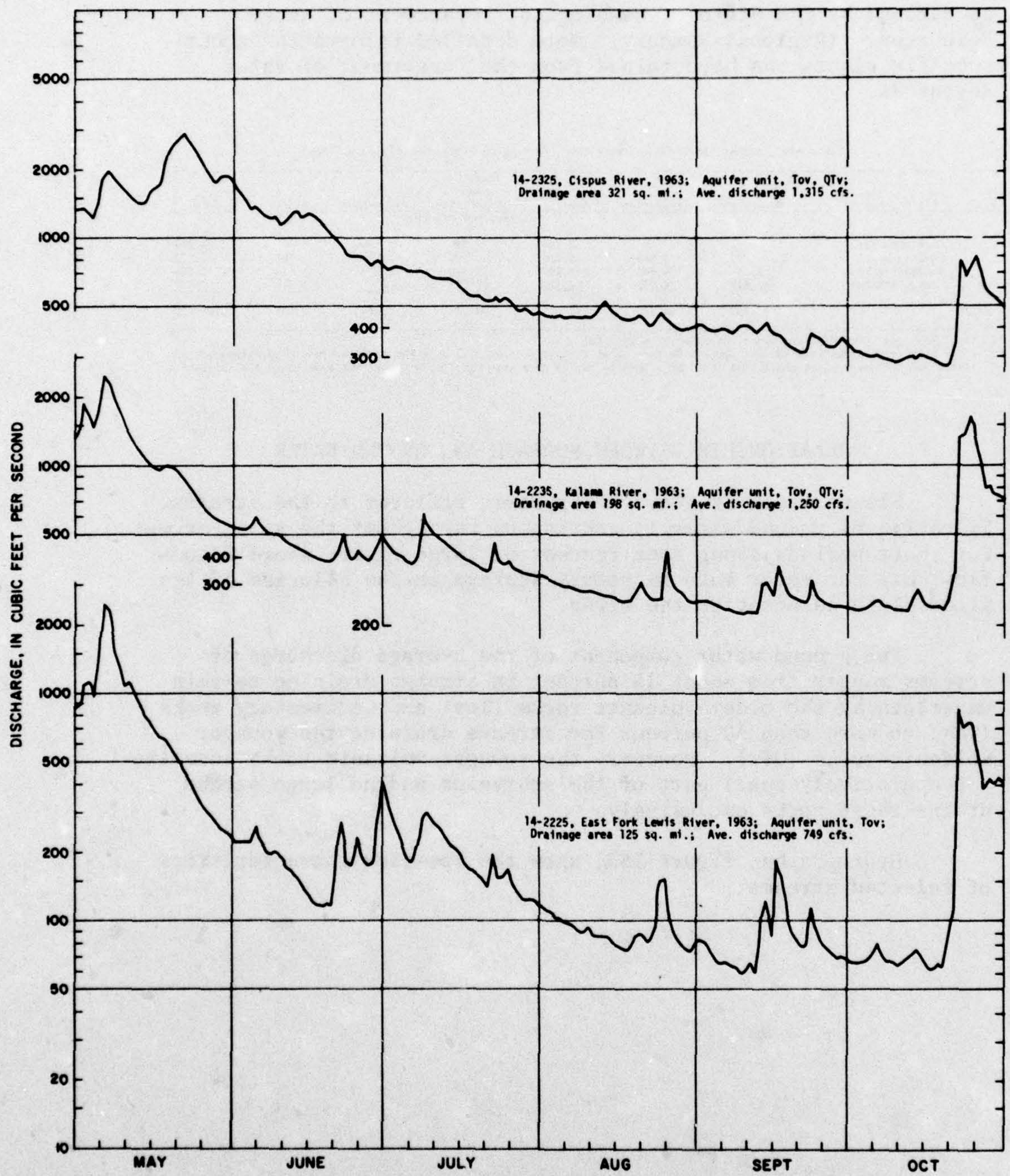


Figure 563 Hydrographs showing low-flow characteristics of selected streams

SUBREGION 9, WILLAMETTE

HYDROLOGIC FRAMEWORK

The Willamette Subregion lies wholly within the State of Oregon and includes all of the area south of the Columbia River between Subregions 7 and 10, as shown on figure 564. The area, encompassing the drainage basin of the Willamette River and its tributaries, extends from the crest of the Coast Range on the west to the crest of the Cascade Range on the east and from the Columbia River southward approximately 150 miles. At the southern end, the foothills of the Coast Range and the Cascades merge to form a natural barrier between the Willamette Basin and the Umpqua River Valley. Elevations within this area range from practically sea level at the confluence of the Willamette and Columbia Rivers to between 5,000 and 6,000 feet along the crest of the Cascades, with a number of peaks extending several thousand feet higher. The average height of the Coast Range in this general area is 1,200 to 2,000 feet with an occasional peak projecting up another 1,000 to 2,000 feet. The area covers 12,046 square miles, of which 166 square miles are water and 11,880 square miles are land, altogether amounting to about 4 1/2 percent of the total area of the region.

Figure 2 shows the major physiographic features of the subregion. A fourth of the Willamette Subregion is a valley floor lying below elevation 500. It is the southern portion of a trough, partly structural and partly erosional, which extends from the vicinity of Cottage Grove northward across Oregon and Washington to and including Puget Sound. The rocks in the Coast Range are a series of sediments, both marine and continental, with some volcanics, whereas the rocks of the Cascade Range are almost entirely composed of lava flows and associated pyroclastics and stream deposits. The valley itself is filled with gravel and sand deposits, and bedrock occurs on the surface only in the Salem Hills and at Oregon City. Mt. Hood in the Cascades is the highest peak, with an elevation of 11,245 feet.

Streams in this subregion averaged about 44 inches of runoff per year or 38,500 cfs during the period 1929-58. The maximum was about 1 1/2 and the minimum about 1/2 times the average.

Except for the Sandy River in the extreme northeast, the Willamette River supplies the entire streamflow from this subregion, its major source being the west slope of the Cascade Range. Here the stream gradients range from about 2 to 8 percent in the upper reaches, but are less than 1/4 percent in the lower valleys.

The principal streams are the Santiam, Middle Fork Willamette, and McKenzie Rivers; others are the Clackamas, Molalla, and Calapooia Rivers. The Santiam River Basin contributes over 60 inches of runoff per year, the Molalla about 50 inches. The others contribute similar amounts, with the greater part occurring during the winter from rainfall.

The other source of Willamette River water is the east slope of the Coast Range. The stream gradients range from about 1 to 10 percent in the upper reaches, but are less than 1/8 percent in the lower valleys. The principal streams are the Yamhill and Tualatin Rivers, others being the Coast Fork Willamette, Long Tom, Marys, and Luckiamute Rivers. The Yamhill River Basin contributes about 40 inches of runoff per year, the Luckiamute a little more, the Marys a little less, and the others about 30 inches.

Glaciers occur on the upper slopes of Mt. Hood, Mt. Jefferson, and the North, Middle, and South Sisters, but cover less than 5 square miles, an insignificant part of the basin. These glaciers exert no appreciable influence on the hydrology because of their small extent and relative stability from year to year. They probably contribute less than 100 cfs to stream discharge during the summer.

About one-third of the subregion area is valley floor, where soils are derived from fine-grained lavas, pyroclastics, marine shale, and sandstone. A fifth of the area contains the soils derived from the sedimentary rocks of the Coast Range, and about half of the total area has the volcanic soils of the Cascade Range.

The half of the subregion area draining the Cascades is densely covered by Douglas-fir forests, with some Western Hemlock, and minor numbers of other softwoods. On the west, the narrower coastal forests are also mostly Douglas-fir, but with a denser ground cover of small trees, shrubs, and vines. The valley floor, however, is nearly all farming area, both dry and irrigated.

The cities of Portland, Eugene, and Salem are the largest of the subregion and had populations in 1960 of 372,680, 50,980, and 49,140, respectively.

CLIMATE

The wide range in elevation explains most of the climatic difference within this subregion.

Some 40 to 50 airline miles to the west of the subregion, the coastline of the Pacific Ocean parallels the Willamette Valley floor. Most large air masses at this latitude move from west to

east; consequently those crossing the Willamette Basin have only a short time previously completed from a few to several days' travel across the Pacific Ocean. In that time the air becomes nearly saturated, and its temperature closely approaches that of the water. The ocean itself is a vast spawning ground for winter storms that several times each winter move on to the Oregon coast, occasionally with considerable violence.

The Coast Range is an effective buffer for the Willamette Basin against the more violent aspects of most winter storms. It is also an important agent in modifying the climate in other ways. Because the land responds much more rapidly to solar heating than water, the air, which arrives at the coastline with nearly ocean temperature, is cooled in winter and heated in summer by contact with the land on its passage inland. Also, air is mechanically cooled from 3 to 5 degrees for each 1,000-foot increase in elevation. The combined cooling in winter, due both to contact and lifting, of this saturated marine air causes large quantities of water vapor to condense and fall out as rain or snow on the west slopes of the Coast Range. A certain amount of this moisture is carried across the crest of these mountains and is deposited on the upper part of their east slopes. As a result of the condensation, this air is much drier as it moves down the east slopes and out over the valley floors. At the same time, its temperature is rising as its elevation decreases, thus increasing its capacity to retain moisture. In summer, the heating of air due to ground contact also increases its moisture-holding capacity. All of these processes result in a considerably lower average relative humidity in the Willamette Valley than in the coastal area. The same pattern of increase in precipitation with increase in elevation, mentioned in connection with movement of air masses across the Coast Range, also occurs as the air moves eastward over the Cascades. The condensation that took place in crossing the Coast Range, however, leaves less moisture available for precipitation on the Cascades.

Precipitation

Along the crest of the Coast Range, annual rainfall averages from 100 to as much as 200 inches. This graduates downward to less than 40 inches on the valley floor and then increases up the west slopes of the Cascades to 60-80 inches, with annual totals as much as 100 inches at a few of the very highest points. Table 315 and figure 564 give precipitation data and location of precipitation stations. Approximately 70 percent of these totals fall in the 5-month period November through March, and only about 5 percent in the three summer months, June-August. Except for the middle and higher slopes of the Cascades, it practically all falls as rain. On the valley floor the total snowfall for an entire winter is

usually not more than 6-8 inches, accumulating to depths of only 2 or 3 inches and melting in a few hours. On rare occasions, depths of 8-12 inches may accumulate at lower elevations, but even these seldom lay on the ground for more than 3 or 4 days. On the west slopes of the Cascades, however, snow depth above 2,000 feet increases sharply with elevation. At Timberline Lodge at an elevation of 6,000 feet, where only a very short record is available, depths have been recorded up to 20 feet and annual totals of 700 inches have fallen. Density of the mountain snowpack increases from about 25 percent water equivalent in early winter to about 40 percent in April.

Table 315 - Average Monthly and Annual Precipitation, Willamette Subregion, 1931-60

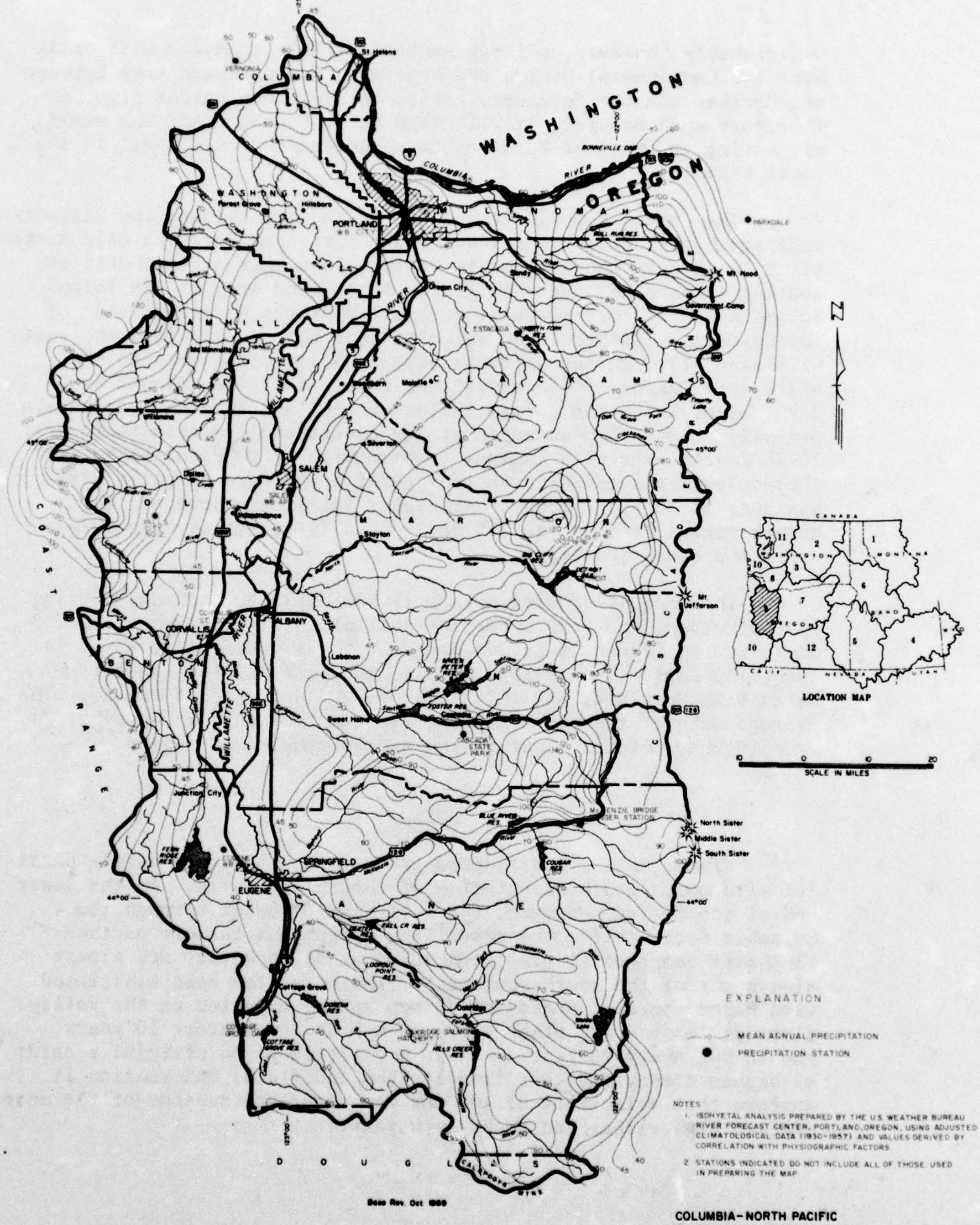
Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Portland WB City	30	6.34	4.90	4.78	2.45	2.05	1.68	.39	.69	1.74	3.89	6.04	7.42	42.37
Estacada 2 SE	414	7.72	6.19	7.02	4.15	3.42	2.83	.62	1.05	2.36	5.77	7.68	8.72	57.53
Salem WB AP	196	6.70	5.31	4.68	2.33	2.11	1.45	.35	.45	1.38	3.91	5.71	7.37	41.75
Detroit	1,452	11.27	9.10	8.58	5.15	3.86	2.86	.59	.89	2.55	7.23	11.05	12.83	75.96
Cascadia RS	796	8.31	6.97	7.32	4.83	3.93	3.05	.57	.82	2.23	5.84	8.05	9.34	61.26
McKenzie Br. RS	1,375	10.48	8.42	8.39	4.75	3.91	2.93	.52	.72	2.25	6.61	9.62	11.84	70.44
Eugene WB AP	364	6.33	4.97	4.32	2.38	2.14	1.42	.27	.40	1.27	3.83	5.62	6.61	39.56
Oakridge Sal. Hat.	1,310	6.73	5.24	5.09	3.10	2.74	2.12	.44	.50	1.32	3.92	5.96	6.81	43.97
Cottage Grove 1 S	650	7.03	5.63	5.45	3.10	2.62	1.85	.30	.49	1.52	4.35	6.47	7.50	46.31
Oregon St. Univ.	240	6.30	4.79	4.12	2.04	1.80	1.24	.31	.38	1.25	3.52	5.35	6.57	37.67
Falls City	550	12.71	10.25	8.74	4.04	2.72	1.48	.34	.62	1.75	5.69	10.78	13.83	72.95
Forest Grove	175	7.54	5.87	5.15	2.32	1.88	1.38	.42	.53	1.49	3.86	6.78	8.52	45.74

1/ Period is no longer or shorter than 30-year normal.

Figure 564 is an isohyetal map prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors.

Temperature

Recorded temperatures in the subregion have ranged from 24°F. below zero to 112°F. above. During most years, however, the annual minimum on the valley floor will not be lower than 5°F. above zero, and, at higher elevations, only 10-15°F. cooler. During most summers, the maximum for the Willamette Basin will not exceed 105°F. Individual stations can expect temperatures of 100°F. or more about every other year. Table 316 and figure 564 show the temperature data and location of weather stations. The more extreme temperatures that do occur are almost always the result of continental air invasions from the east. During winter, large masses of Arctic air form over the ice and snow fields and very cold land masses of northern and central Canada. At intervals these will push southward along the east slope of the Rocky Mountains.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

WILLAMETTE SUBREGION 9

1968

FIGURE 564

Occasionally, however, a large segment of this cold air will break over the Continental Divide and continue its southward trek between the Rockies and the Cascades. Since this is much colder air, and therefore much heavier, it will tend to push underneath the marine air moving in from the Pacific Ocean and cause a cold spell in the local climate.

The Columbia Gorge is the one passageway through the Cascades that provides a nearly sea level route for a part of this cold Arctic air to push into the Willamette Basin. In summer a great deal of heating takes place over the fairly broad land area of the inland Columbia Basin. Occasionally pressure patterns on either side of the Cascades will become so oriented that hot dry air from the east will sweep through the Columbia Gorge and lower passes into the Willamette Basin. These conditions rarely last more than 2 or 3 days, after which the normal inflow of cool air from the west again prevails. Long-term averages at low elevations indicate there are 10-15 days a year with maximum temperatures of 90°F. or higher. At these elevations there is an average of 50-60 days annually with minimums of 32°F. or lower. At higher locations, however, this number ranges from 100 to 250 days annually--possibly even more, depending upon elevation.

The longest growing season is 263 days at Portland. Moving up the valley, the season becomes shorter until at Salem it is 213 days, and at Eugene it is 205 days; at the 1,000-foot level it is about 150 days. The average date of the last killing frost is March 6 at Portland, April 1 at Salem, and April 13 at Eugene. The average date of the first killing frost in the fall is November 24 at Portland, October 31 at Salem, and November 4 at Eugene.

Wind

Winds, in the lower speed categories, move very nearly parallel with north-south orientation of the valley walls. At the lower end of the valley, however, the east-west movement through the Columbia Gorge shifts the prevailing directions to more northwest-southeast components. The high speed winds, however, are almost always out of the south-southwest. These are the ones associated with major storms. Speeds of 40 mph can be expected on the valley floor at least every other year, 60 mph at least every 10 years, and 70 mph every 25 years. There are little or no official records at higher elevations, but from limited unofficial information it appears that velocities of 100 mph may occur across some of the more exposed high ridges and peaks each year.

Table 316. Average and Extreme Temperatures (^{o}F), Willamette Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Portland WB City	Av. Max.	44.3	48.7	54.7	61.4	67.4	72.1	78.5	77.9	72.4	63.0	52.3	46.6	61.6
(86)	Av. Min.	34.5	37.0	40.1	43.7	48.5	53.2	56.9	56.7	53.0	47.6	41.0	37.3	45.8
	Mean	40.2	43.8	47.7	53.5	59.1	63.4	68.6	68.1	64.5	56.5	47.2	43.1	54.6
	Highest	65	68	83	93	99	102	107	102	102	90	73	65	107
	Lowest	-2	7	20	28	32	39	43	43	35	29	11	3	-2
Salem WB AP	Av. Max.	45.0	50.2	55.4	62.4	68.5	74.3	82.4	81.9	76.7	64.9	52.8	47.6	63.5
(32)	Av. Min.	31.8	34.0	36.3	39.3	43.7	48.3	50.5	50.4	47.3	42.8	37.0	35.0	41.4
	Mean	38.5	41.9	45.3	51.1	56.3	60.6	66.1	66.1	62.5	54.1	45.2	41.5	52.4
	Highest	64	67	80	88	95	102	108	104	103	92	69	72	108
	Lowest	-10	-4	19	24	25	34	35	35	26	26	9	5	-10
Cascadia RS 1/	Av. Max.	44.2	49.4	54.5	62.4	68.9	73.5	82.0	81.8	76.4	63.9	51.8	45.1	62.8
(27)	Av. Min.	29.3	31.8	33.9	37.4	42.3	46.4	48.5	48.0	44.3	40.1	35.0	32.9	39.2
	Mean	37.0	40.7	44.2	49.8	55.2	60.3	65.2	64.7	60.3	51.7	43.4	39.8	51.0
	Highest	65	73	85	94	96	101	106	104	102	92	79	64	106
	Lowest	1	4	19	24	25	30	33	35	28	24	10	1	1
Eugene WB AP 1/	Av. Max.	45.0	50.7	54.2	61.3	68.0	73.3	82.2	80.7	76.7	63.8	52.9	47.3	63.0
(18)	Av. Min.	32.1	34.7	35.9	39.3	43.8	48.1	50.6	50.0	46.7	41.8	37.1	34.8	41.2
	Mean	39.1	42.6	46.0	50.8	56.1	60.9	66.6	65.9	61.5	53.2	45.5	41.8	52.5
	Highest	64	69	74	86	91	100	105	100	101	87	71	67	105
	Lowest	-4	-3	20	27	28	35	39	38	32	24	14	16	-4
Oakridge Sal. Hat.	Av. Max.	45.9	52.2	58.7	64.9	71.3	76.2	85.0	85.4	80.0	68.4	55.2	47.5	65.9
(30) 1/	Av. Min.	30.2	32.6	34.0	30.0	42.3	47.2	50.6	49.5	45.6	41.6	35.2	32.6	40.0
	Mean	37.6	42.4	46.6	51.6	56.8	61.5	68.0	67.4	62.8	54.7	45.2	40.0	52.9
	Highest	65	78	86	97	102	110	112	110	108	99	78	66	112
	Lowest	0	10	19	25	21	32	33	34	29	24	17	1	0
Falls City	Av. Max.	44.4	49.4	54.0	61.2	67.1	72.3	80.5	80.4	74.3	63.5	52.5	46.5	62.2
(48)	Av. Min.	31.2	33.4	35.3	38.0	41.8	45.7	47.8	47.8	46.2	42.0	36.5	33.5	39.9
	Mean	37.9	41.1	44.4	49.5	54.8	59.2	64.4	64.5	61.4	53.4	44.3	40.5	51.3
	Highest	68	67	82	88	92	102	106	102	100	90	74	63	106
	Lowest	-5	1	18	23	26	32	36	36	26	23	10	-2	-5
Forest Grove	Av. Max.	43.6	48.7	54.9	62.3	69.3	74.8	82.3	82.6	75.2	63.9	51.9	45.6	62.9
(63)	Av. Min.	31.0	33.0	35.4	38.4	43.2	47.5	50.2	50.1	46.8	41.4	36.4	33.7	40.6
	Mean	37.5	41.3	45.4	51.1	57.0	61.5	66.6	66.2	62.1	53.1	44.1	40.4	52.2
	Highest	62	77	82	93	98	101	109	103	104	91	77	64	109
	Lowest	-18	-15	16	21	28	34	34	35	27	22	7	-15	-18

1/ Period is longer or shorter than the 30-year normal.

Note: The mean temperature is for the normal period 1931-60; other data are for the period of record through 1960. Numbers under station names denote full years of record.

Evaporation

Annual evaporation from a Class A pan in the Willamette Valley is between 30 and 40 inches. Potential evapotranspiration ranges from about 25 inches on the valley floor to 20 inches on the upper slopes due to lower temperatures at the higher elevations. In contrast, the actual evapotranspiration tends to increase slightly with height because the heavier rainfall provides more moisture to evaporate from the soil. For soils with 2-inch holding capacity the actual evapotranspiration increases from 12 inches on the valley floor to 16 inches at higher elevations, and for those with 6-inch holding capacity it increases from 15 inches on the valley floor to near 18 inches at higher elevations.

Storms

Nearly all of the widespread winter precipitation in the subregion is produced either by a family of mature occlusions or by a quasi-stationary front with active minor waves. These storms may extend many hundreds of miles to the north or south. Tropical cyclones are extremely rare, and thunderstorms are of local rather than general occurrence, the greater number occurring over the mountains in summer. Infrequent hail or sleet storms occur but seldom reach destructive proportions

Humidity

Relative humidity during the early morning hours may be near 100 percent any time of the year. The 4:00 a.m. average on a year-round basis is between 80 percent and 90 percent. During the warmer part of the day, however, there is a considerable variation from winter to summer. The 4:00 p.m. average ranges from 80 percent in December to about 30 percent in July, occasionally falling to less than 20 percent.

Sunshine

Marine influence combined with normal storm patterns across this area in the late fall, winter, and early spring results in much cloudiness. This reaches its peak in December when, on an average, nearly 90 percent of the sky is cloud-covered the entire month. This diminishes to about a 40 percent cover in July. There are, on the basis of a fairly long period of record in Portland, Eugene, and Salem an average of 70-75 clear days a year, 80-85 partly cloudy, and 200-210 cloudy ones. The amount of sunshine

varies from 20 percent of possible during December to 75 percent of possible during July. Fog rarely occurs during the summer but is common from October through February.

SURFACE WATER

The rivers of the Willamette Subregion are well used, the water supply is copious, and the quality is generally good. The runoff is primarily from winter rainfall, with varying amounts of snowmelt included. Flood flows are highly regulated by flood control reservoirs; three on the Santiam, two on the McKenzie, three on the Middle Fork, two on the Coast Fork, and one on the Long Tom River.

Water is used for power generation at all of the Santiam and two of the Middle Fork reservoirs and at many smaller reservoirs of private power companies, particularly on the McKenzie, Clackamas, and Willamette Rivers.

Early irrigation development was slow in the Willamette Basin. However, since 1950, there has been a more rapid expansion in sprinkling from both surface and ground water, which is practiced throughout the valley floor.

Navigational use of water is important on the Willamette River up to Salem, with decreasing use farther upstream.

Quantity

Average discharge of streams in the subregion totals about 38,490 cfs (27.9 million acre-feet annually). This averages 3.2 cfs per square mile, one of the highest rates in the Columbia-North Pacific Region.

Present Utilization

About 4.4 percent of the average discharge was withdrawn in 1965 for consumptive uses, but only about 1.4 percent was actually consumed. About one-sixth of the water withdrawn for consumptive uses (about 1,680 cfs) was for municipal supplies (163 cfs domestic and 118 cfs industrial); the largest user was self-supplied industry (800 cfs). Irrigation was the second largest user (538 cfs) but the major consumer--377 cfs of the total of 522 cfs consumed in the subregion. A very small flow was used for thermal power cooling, but there was appreciable steam power generation. A small quantity of water was used to generate hydroelectric power. Navigation takes place throughout the main stem of the Willamette River,

with large volumes of ocean-going traffic reaching the Portland harbor. Recreation is popular and water use for it is growing rapidly. With the mild climate and abundance of water, recreation is becoming a major industry. All waters are used to some degree for fish and wildlife. The abundance of water makes it generally available for the transport and dilution of waste, but pollution is a problem in the lower reaches of some streams, particularly the main stem of the Willamette River.

Stream Management

Competition for water among the various users necessitates efficient stream management. Storage and release, diversions, conservation, legal constraints, etc., all are a part of the water-management system.

Impoundments Reservoirs having a total capacity of 5,000 acre-feet or more are listed in table 317. Lookout Point Reservoir on the Middle Fork Willamette River is the largest impoundment in the subregion, but Detroit and Green Peter reservoirs are almost as large. The table includes the 11 flood control and power reservoirs mentioned earlier, plus eight other reservoirs. Only four of the reservoirs are single-purpose.

Table 317 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More, Subregion 9

Name	Stream	Total Storage (ac-ft)	Active Storage (ac-ft)	Surface Area (acres)	Purpose 1/
Big Cliff	N. Santiam R.	5,930	2,630	141	P
Blue River	Blue R.	89,000	85,000	975	AFINR
Lake Ben Morrow	Bull Run R.	30,680	30,680	385	MP
Bull Run No. 2	Bull Run R.	20,990	20,990	420	MP
Cottage Grove	C. F. Willamette R.	32,940	30,060	1,160	ACFINR
Cougar	S. F. McKenzie R.	219,300	165,130	1,230	ACFIMNPR
Detroit	N. Santiam R.	455,000	340,000	3,580	CFINPR
Dexter	M. F. Willamette R.	27,500	4,800	1,025	PR
Dorena	Row R.	77,500	70,500	1,835	CFINR
Fall Creek	Fall Cr.	125,000	115,000	1,820	ACFIMNPR
Fern Ridge	Long Tom R. & Coyote Cr.	116,200	109,200	10,400	CFINR
Foster	S. Santiam R.	61,000	33,600	1,220	AFINPR
Green Peter	Mid. Santiam R..	410,000	333,000	3,610	ACFINPR
Hills Creek	M.F. Willamette R.	356,000	249,000	2,710	ACFIMNPRW
Lookout Point	M.F. Willamette R.	456,000	349,400	4,360	ACFINPR
North Fork	Clackamas R.	18,600	5,990	350	P
River Mill	Clackamas R.	12,200	770	-	P
Smith	Smith R.	15,000	9,900	170	P
Timothy Lake	Oak Grove Fork	65,710	61,650	1,400	PR

1/ A-pollution abatement, C-conservation, F-flood control, I-irrigation, M-municipal, N-navigation, P-power, R-recreation, W-industrial.

Operation of flood control reservoirs generally follows a pattern of discharging during September and October, if not evacuated earlier for conservation uses, maintaining active capacity empty during November, December, and January; and filling during February, March, and April.

The impoundments have variable short-term effects on river discharge. The changes in discharge due to power loads are abrupt, and, on weekends when less power is required, flows may be low. Municipal water is supplied from storage during the summer, principally to satisfy lawn-watering and air-conditioning needs. Irrigation water is supplied at a fairly constant rate from April through September. On the other hand, recreation use requires that the water be retained in the reservoirs as long as possible during the summer. Flood control operation causes rapid filling of reservoirs during winter floods, with steady evacuation during a period of about 10 days immediately after each flood.

Diversions Most of the water diverted in the Willamette Subregion is for power and irrigation. Other diversions are made for municipal, industrial, drainage, and flood control uses, and to operate fish hatcheries. Although there are many diversions in the subregion the quantity of water involved is small. Some of these are listed with their uses in table 318.

Table 318 - Stream Diversions and Uses in Willamette Subregion

	Diversion Uses					
River Basin	Power	Irrigation	Municipal	Industrial	Drainage	Flood Control
McKenzie	Carmen Tunnel					
	Smith Tunnel					
	Leaburg Canal					
	Walterville Canal	McKenzie Ditch				
Long Tom						Amazon Diversion Channel
Santiam		Brownsville Ditch				
		Sodom Ditch			Sodom Ditch 1/	
	Lebanon Ditch		Lebanon Ditch 1/			
	Santiam Canal		Santiam Canal 1/			
		Peters Ditch				
	Salem Canal			Salem Canal 1/		
		W. Stayton Ditch				
		Sidney Canal				
		Lacomb Canal				
Coffee L. Cr.		Seeley Ditch				
Pudding		Lake Labish Ditch			Lake Labish Ditch 1/	Shelton Ditch
Tualatin	Oswego Canal					
		Cummings Ditch				
Clackamas	Faraday Lake Flume					
Sandy	Roslyn Lake Flume					

1/ Second use for the same diversion

Channel Modification Throughout the Willamette River and some major tributaries, channel modifications in the form of levees, revetments, channel rectification, and dredging have aided flood control, reduced erosion, and maintained depths adequate for navigation. Revetments of large stones to protect river banks are numerous in the reach from Salem to Eugene, and in the lower Santiam, McKenzie, and Middle Fork Willamette Rivers. Dredging is accomplished annually in the Willamette River to maintain depths for navigation. Levee systems for flood protection have been constructed along portions of the lower reaches of rivers near population centers, and are maintained by local interests.

Forecasting Forecasting is used in flood control operations of reservoirs, flood warning, and to provide a maximum of stored water for power generation, municipal use and irrigation. The Willamette flood-warning system combines Telemark instruments with both telephonic and radio transmission from numerous locations to a central point in Portland. The Weather Bureau is officially responsible for providing a flood-warning service to the general public at times of major flooding.

Forecasts of seasonal quantities of water available for storage are made using snow-survey data, precipitation data, data on antecedent conditions, and other parameters. The information is processed by digital computer and updated each month as new data are obtained.

Constraints There are no interstate compacts or international treaties that are concerned with runoff in the Willamette Subregion; the 1961 treaty with Canada concerning the Columbia River will have only indirect effects on the Willamette River. However, many restrictions are involved in the operation of the Willamette Basin reservoirs.

The first consideration is to maintain, as nearly as possible, sufficient minimum flow to satisfy prior water rights. The next requirement is the flow of water advocated by the Federal Fish and Wildlife Service and the Oregon State Fish and Game Commissions as adequate for the normal resident fish population and the anadromous fish runs. When power requirements are critical, a higher release of water is made, unless flood conditions are also critical, in which case the lower flood release controls. Should irrigation demands become excessive before all authorized and recommended reservoirs are built in the Willamette River Basin, all reservoirs in the Willamette system could be required to furnish irrigation water to the possible detriment of other conservation

needs. Finally, operation for navigation requires increased flows during the low-water season. When all the presently authorized and recommended dams have been constructed, the goal is to maintain minimum flows of 5,000 cfs at Albany and 6,000 cfs at Salem in 75 percent of the years. Maximum rates of change in discharge are also specified for each dam in the Willamette system.

Water Rights

The water resource inventory areas, as defined by the State of Oregon Water Resources Board, are shown on figure 565.

Discharge

A typical Subregion 9 stream, Willamette River at Albany, Oregon, shows a base-period (1929-58) mean discharge equal to 104 percent of its 70-year long-term mean (1896-1965). Weather records show that precipitation in Albany during the base period was 97 percent of the long-term mean (87 years, 1879-1965). Thus, the selected base period provides reasonably average data for statistical analysis.

Measurement Facilities Table 319 summarizes pertinent streamflow data for 19 sites selected for detailed study in Subregion 9.

Table 319 Streamflow Summary for Selected Sites
Subregion 9

Stream	Station	Station Number	Gage Datum	Drainage Area (sq mi)	Period of Record	Annual Flow[1] (cfs) Mean	Annual Flow[1] (cfs) Max.	Annual Flow[1] (cfs) Min.	Momentary Flow[2] (cfs) Max.	Momentary Flow[2] (cfs) Min.
Sandy River	Bull Run	1425	200	440	30-65[3]	2,302	3,360	1,368	84,400	45
Mid. Fk. Willamette R.	Jasper	1520	513.45	1,340	53-65[3]	3,916	6,319	2,130	94,000	366
Coast Fk. Willamette	Goshen	1575	473.80	642	51-65[3]	1,512	2,700	705	58,500	36
McKenzie River	Coburg	1655	396.32	1,337	44-65	5,508	8,242	3,170	88,200	1,250
Long Tom River	Monroe	1700	270.57	391	27-65[3]	770	1,534	328	19,300	0
Mary's River	Philomath	1710	218	159	40-65	441	759	237	13,600	4.7
Calapooia River	Holley	1720	527.58	105	35-65	438	662	221	12,600	18
Willamette River	Albany	1740	167.18	4,840	96-65[3]	14,111	23,744	7,646	266,000	1,840
North Santiam River	Niagara	1815	1093.78	453	39-65[3]	2,102	3,175	1,424	63,200	19
South Santiam River	Waterloo	1875	370.39	640	24-65[3]	2,856	4,509	1,741	95,200	96
Santiam River	Jefferson	1890	199.63	1,790	39-65[3]	7,596	11,722	4,656	197,000	260
Luckiamute River	Suver	1905	171.92	240	39-65[3]	903	1,414	462	32,900	13
Willamette River	Salem	1910	106.14	7,280	23-65[3]	22,991	36,334	13,529	348,000	2,470
South Yamhill River	Whiteson	1940	82.30	502	40-65	1,611	2,944	844	47,200	8.5
Molalla River	Canby	2000	104.00	323	63-65[3]	1,135	1,822	638	43,600	20
Pudding River	Aurora	2020	72.23	479	29-64	1,215	1,980	695	25,400	26
Tualatin River	West Linn	2075	85.61	710	28-65	1,443	2,643	671	29,300	13
Willamette River	Oregon City	2077	-	10,008	-	29,900	43,694	17,660	-	-
Clackamas River	Estacada	2100	296.93	671	08-65	2,674	3,710	1,712	86,900	50

1/ Regulated values for base period (1929-58) with estimated 1970 conditions of development.
2/ Maximum and minimum observed instantaneous values for period of record.
3/ Denotes other short periods of record prior to dates shown.

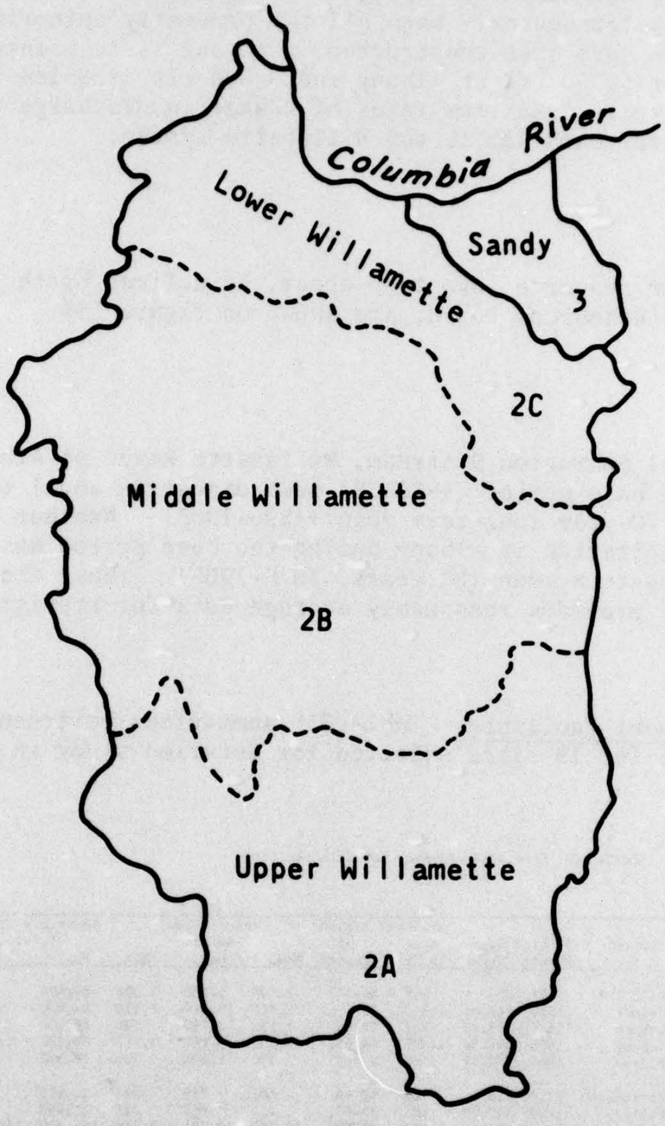


Figure 565 Map showing water resource inventory areas defined by the State of Oregon Water Resources Board.

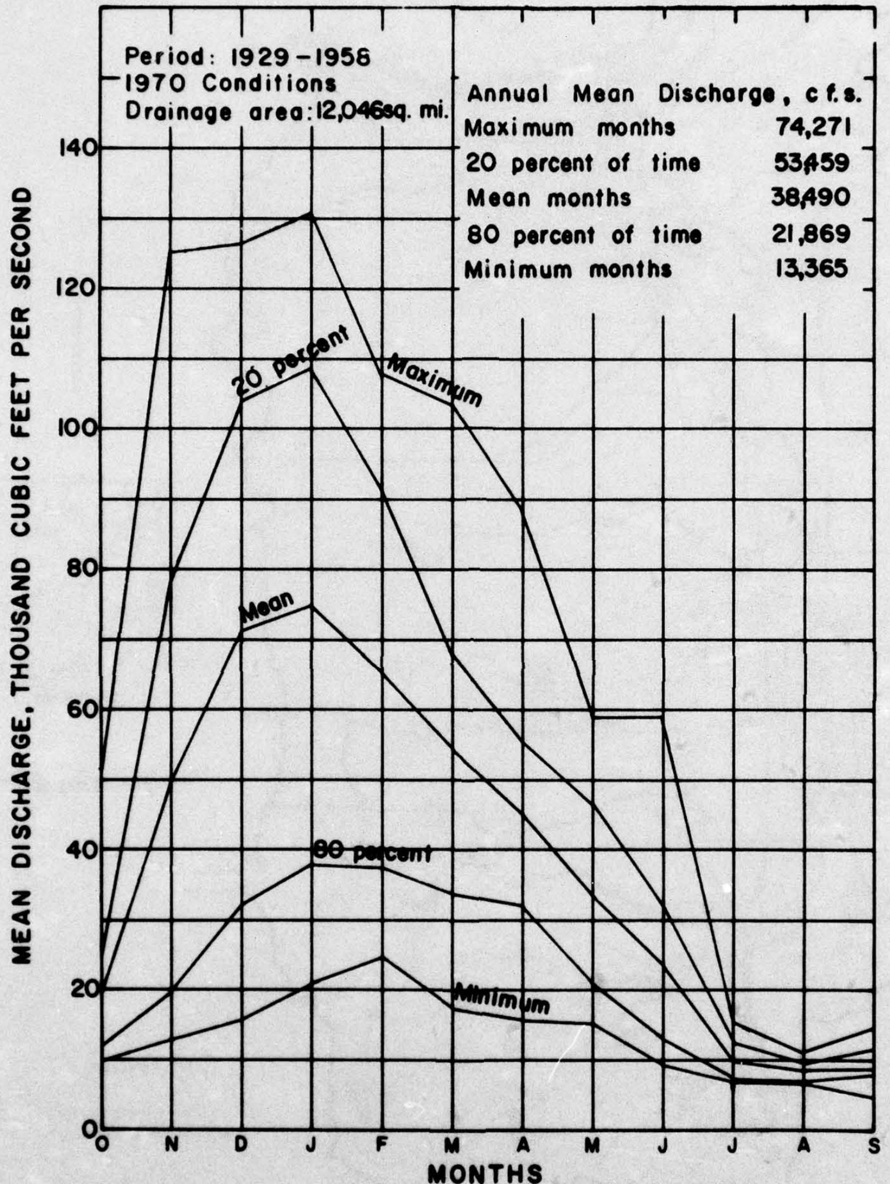
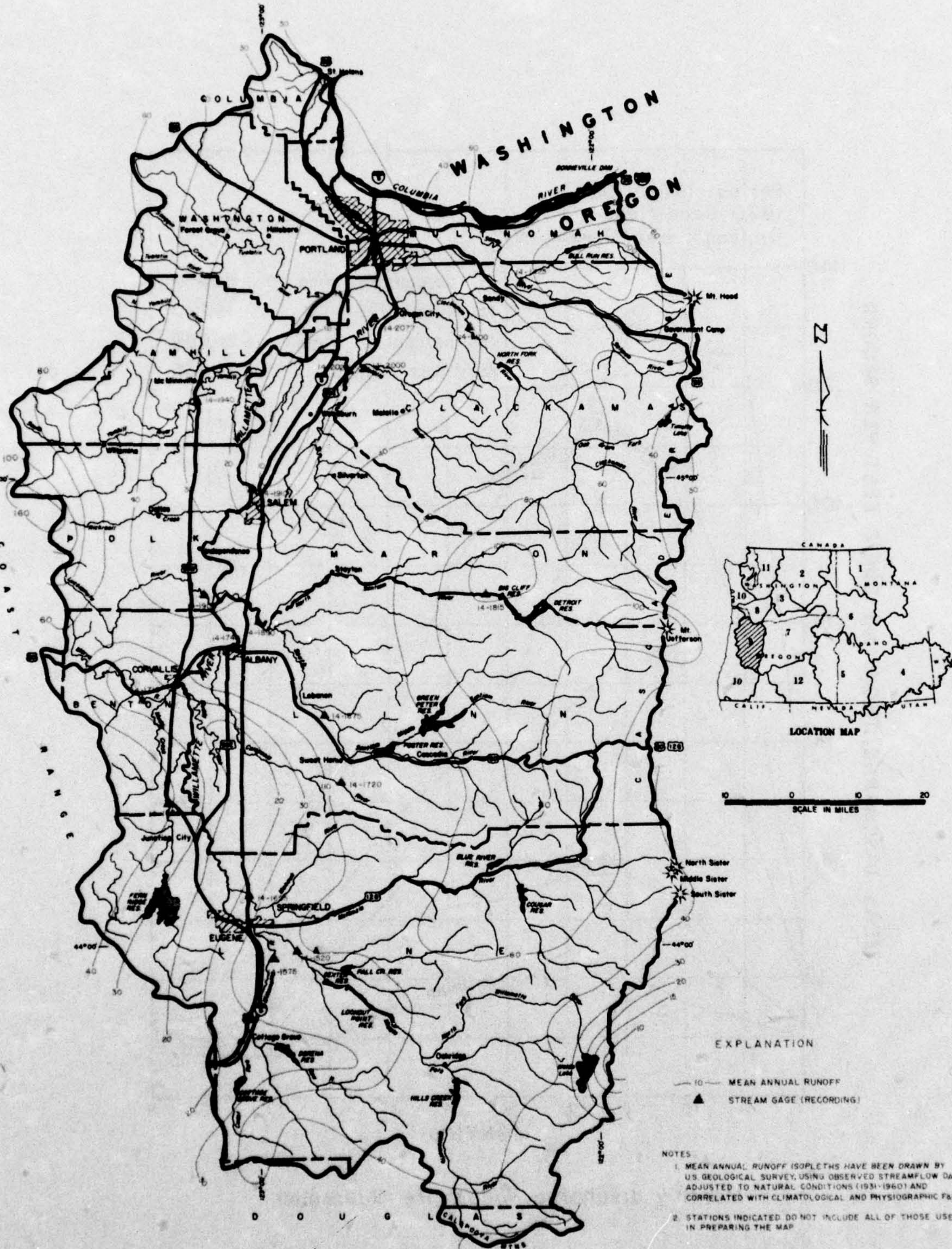


Figure 566 Monthly discharge, Willamette Subregion



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

WILLAMETTE SUBREGION 9

1968

FIGURE 567

Figure 567 shows the locations of the selected sites, with Geological Survey identification numbers. The first two digits of the identification number, part number 14, indicate that Subregion 9 lies within the area designated as Part 14, Pacific slope basins in Oregon and lower Columbia River Basin.

<u>Average Discharge for Subregion 9</u> Figure 566 presents monthly discharge data for the subregion as a whole. The discharge is the sum of the Willamette and Sandy River flows and is entirely generated within the subregion. It reaches a maximum in January, is sustained by spring snowmelt, and gradually recedes to a minimum in August. The flows are shown in table 320. Isopleths showing mean annual runoff for the period 1931-60 are shown on figure 567.

Table 320. Discharge in Willamette Subregion, 1929-58
(Mean discharge, in cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
							Maximum						
Subregion	51,170	125,065	126,420	130,225	108,190	103,070	88,160	58,970	58,815	15,560	11,095	14,510	74,271
							20 percent						
Subregion	24,390	77,645	104,060	108,425	91,335	68,045	55,500	46,545	31,980	12,780	9,575	11,225	53,459
							Mean						
Subregion	19,560	49,371	70,372	74,011	64,837	54,037	44,795	33,480	23,656	9,991	8,271	9,499	38,490
							80 percent						
Subregion	11,945	19,595	31,950	37,455	37,145	33,855	31,990	20,525	15,175	7,730	7,145	7,915	21,869
							Minimum						
Subregion	9,945	12,885	15,600	20,765	24,195	17,830	15,935	15,030	9,295	7,065	6,870	4,965	13,365

NOTE: 1. Subregion discharge is that which originates in the subregion
2. Twenty percent and eighty percent represent the discharge available 20 and 80 percent of the time.

<u>Average Discharge for Selected Stations</u> In this section of the report, detailed data are presented for each of the selected sites listed in table 319, plus the entire subregion, which includes Sandy River and all other subregion discharges.

The monthly discharges presented for the eight stations Bull Run, Philomath, Suver, Whiteson, Canby, Aurora, West Linn, and Estacada are available in Geological Survey Water-Supply Papers 1318 and 1738, compilations of surface-water records in Part 14. For the remaining stations, an assumed plan of reservoir regulation has provided adjusted flows through a computer program. Records for most of the sites have been extended by correlation with nearby stations. Since most of the sites required some change in records, the values shown in tables 321 to 340 for the most part have been termed either observed or modified mean discharges. Hydrographs for several conditions of flow at the selected sites are shown on figures 568 to 586. Explanations of these and the succeeding graphs are in the Regional Summary.

Frequency curves of annual high and low discharges are shown on figures 587 to 605. The slopes of the curves from one stream to another are very nearly the same, revealing the remarkable uniformity in variation from years of high flow to those of low flow. However, the spread of the curves from 1-month to 12-month flows is highly variable. For example, the western tributaries generally show a wide spread, indicating greater short-period extremes in runoff associated with less infiltration and light snowpacks; in fact, the curves for Tualatin River, figure 603, had to be shown on two sheets. On the other hand, curves for the McKenzie, North Santiam, and Clackamas Rivers, figures 590, 595, and 605, are close together, showing the regulating effect of deep snowpacks and the porous volcanic soils.

Duration curves for three flow conditions, daily, monthly, and annual, are presented in figures 606 to 624. The monthly and annual discharges used are those of tables 321 to 340, but the daily flows are observed for the period of record as provided in the Geological Survey daily summaries. Again the greater variability in monthly flows is depicted for west-side tributaries.

Frequency curves of annual peak flows are shown in figures 625 to 640. Curves for both regulated and unregulated conditions are presented where flows are modified by reservoirs, the station exhibiting the greatest regulatory effect being the Middle Fork Willamette River at Jasper, figure 626. As pointed out earlier, the range in peak flows from one stream to another is fairly constant, as indicated by the slopes of the curves. The greatest variability from one year to another is shown for the Clackamas River at Estacada, figure 640, but this is partly due to the longer period of record.

Dependable yields of the rivers in the subregion are given in tables 341 to 359. Each table shows the lowest mean flows for from one to ten consecutive years in the 30-year base period and their relationship to the 30-year mean. The difference between any two flows is a measure of the reservoir storage capacity required to make the higher flow available. The west-side tributaries would require relatively more storage, with the Long Tom River at Monroe, table 345, having a minimum-year flow of only 42 percent of the 30-year mean. On the other hand, the minimum-year flow of the North Santiam River at Niagara, table 349, is 67 percent of the mean. The average minimum-year discharge is 56 percent of the mean.

<u>Variations in Discharge</u> Long-term variations in discharge and precipitation are presented in figures 641, 642, and 643 for a typical Willamette River station, west-side tributary, and east-side tributary. The annual means for the base period for the entire

period of record are shown. Although the annual precipitation for a given year varied from the mean by as much as 49 percent, the 5-year moving average varied from the mean by no more than 24 percent.

The 5-year moving averages are also presented in order to indicate trends more clearly. There has been a general decline in precipitation and streamflow from 1895 to 1945, with recovery since then. An interesting observation for the Willamette River is that streamflow during the period 1945-60 was much greater than during the period 1890-1905, but precipitation during the recent period was less than during the earlier period. It seems the percentage of runoff has been increasing.

As pointed out earlier in the discussions on duration curves and frequency curves, the variation in annual flows at selected sites during the 30-year base period is relatively small and uniform among the sites. The maximum annual discharge is generally about 3.0 times the minimum annual discharge, ranging from 2.2 for the Clackamas River to 4.7 for the Long Tom River.

Seasonal variations in runoff are clearly shown in the hydrographs of figures 568 to 586. Two peaks are shown for the east-side tributaries, one during the winter and the other in the spring. The winter peak is the larger and is due primarily to rainfall, whereas the spring peak is mainly snowmelt runoff. For the west-side tributaries, only the winter rainfall peak occurs. The low runoff months are July, August, and September. Streams with deep snowpacks and large underground reservoirs, such as the McKenzie River, have the smallest variations in monthly flows.

Streamflow Travel Time With the cooperation of several Federal and state agencies, time-of-travel studies have been made for a number of streams, including the main Willamette River, the Coast Fork, McKenzie, North Santiam, South Santiam and Yamhill Rivers. Plots of accumulated time in hours versus river mile for various discharges are shown in figures 644 to 649. The travel time for low and moderate discharges was determined by injections of rhodamine B dye into the river and detecting the leading edge downstream by visual observation and by fluorometer (optical instrument). The resulting velocity was reduced about 10 percent to obtain the average particle velocity through the river reach.

High-flow travel time was determined by hydrograph inspection and flood routing computations and is based on velocity of the flood wave. The high-flow travel time from Salem to Oregon City in Willamette River is 25 minutes per mile; low flow, 148 minutes per

mile. Travel times in minutes per mile for the lower 10 miles of all six rivers are as follows:

River	High Flow	Low Flow
McKenzie	12	36
North Santiam	-	42
South Santiam	12	130
Yamhill	-	300
Coast Fork	18	110
Willamette	54	300

River Profiles Profiles for selected streams are shown on figures 650 to 653. The profiles were constructed from Geological Survey plan and profile sheets, topographic maps, and data from available reports.

(Narrative continued on page 745)

Table 321 - Observed Mean Discharges, in CFS, Sandy River Below Bull Run River near Bull Run, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										215	114	165	
1929	895	1770	1925	2040	1295	3420	3305	3695	2425	705	440	385	1858
1930	380	345	2960	1420	5940	2400	1880	2380	1450	520	395	350	1670
1931	750	1610	1550	2300	1460	4320	4150	1320	1070	605	375	385	1660
1932	865	2420	1990	3340	2190	6430	3940	3500	1720	765	505	405	2340
1933	785	5320	3490	4100	2250	3260	3540	4390	4890	1210	670	1170	2920
1934	1925	2660	9445	6405	1555	3540	2110	1250	725	475	395	360	2591
1935	1420	4465	4820	3015	2540	2570	3045	2785	1235	855	475	405	2300
1936	430	770	1470	6480	2230	3170	3575	3235	1735	770	455	455	2068
1937	375	350	2500	790	2025	3630	5175	4325	3155	975	535	455	2021
1938	870	5130	5235	4295	2290	3510	4560	2595	955	555	420	385	2567
1939	435	2440	3150	2695	3355	3455	3035	1835	1700	800	435	365	1965
1940	580	620	2830	1505	5155	3925	2775	1630	570	410	320	360	1711
1941	540	2665	2145	2525	1255	995	980	2135	1275	530	400	970	1368
1942	1405	2270	4405	1650	3015	2010	2100	2770	2060	1020	505	370	1959
1943	455	6785	6770	3710	5245	2935	5015	3225	2470	975	590	455	3197
1944	1150	1765	1850	1470	2150	2135	2980	2205	1505	620	425	500	1559
1945	455	1085	1255	3785	3970	2565	3940	5040	1295	610	445	560	2073
1946	440	3967	5090	4180	2890	3315	2795	2945	1810	1140	525	420	2458
1947	1790	4145	7080	3700	2875	2370	2665	1055	1745	845	470	460	2432
1948	3655	5645	2710	4245	4095	2400	2995	3730	2060	875	635	610	2796
1949	1390	3630	4790	1145	3785	3125	4090	5360	1710	830	575	625	2577
1950	1500	2490	3395	3145	4935	4390	3875	4135	3880	1245	655	575	2836
1951	2390	5010	4720	5830	4450	2685	3300	3180	1080	630	445	395	2834
1952	3030	2385	3710	1635	3760	2430	3250	2900	1585	1045	515	390	2214
1953	325	295	990	8955	5160	2720	2425	3350	2275	815	530	435	2344
1954	490	2910	6765	3660	4305	2220	3340	2365	3265	1460	690	760	2673
1955	1450	1910	2805	2440	2520	1790	3335	4090	4425	1755	685	610	2313
1956	2970	6955	6340	5565	2055	3795	3900	3925	2610	890	715	545	3360
1957	1875	2245	4900	1345	2535	4905	3995	2455	1275	615	465	380	2250
1958	565	1495	5635	4040	4480	1755	4660	1565	1255	740	470	500	2248
Mean	1186	2851	3890	3280	3192	3072	3357	2979	1973	843	505	501	2302

Table 322 - Modified Mean Discharges, in CFS, Middle Fork Willamette River at Jasper, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										4895	10933	6155	
1929	2325	4226	1586	3922	2979	2947	3117	1688	3291	1222	2418	1861	2632
1930	2519	3387	4625	3237	4003	2084	1987	1710	2963	1508	3077	2214	2776
1931	2037	1457	1911	2251	1702	2707	2690	1298	2796	1653	2973	2086	2130
1932	1055	2242	3136	4987	2972	5922	4551	5469	5897	2017	1607	2134	3499
1933	3432	6930	4971	6891	4602	3435	2005	4123	9846	2761	1755	2469	4435
1934	3512	4704	4710	7461	1292	1298	1640	1847	2425	2317	2940	1110	2938
1935	1388	4194	8711	6448	1758	2791	2169	3275	4887	1678	2235	1616	3429
1936	2955	4860	3011	9776	3296	2577	1720	3026	4023	1605	2034	1727	3384
1937	3090	4143	2295	1332	4543	4305	4907	4077	7073	2155	1615	2324	3488
1938	3889	9974	7141	7631	4654	4982	4396	4402	3903	1625	2707	1815	4760
1939	2508	6264	3853	3781	3849	3591	1596	1576	3343	1619	3159	2179	3110
1940	2308	3649	3279	2058	2671	3693	1606	1471	2692	2197	3209	1884	2560
1941	2596	3341	3595	4486	1475	1395	1554	1478	2197	1649	3181	1905	2404
1942	1123	3863	9411	4723	2297	1760	1540	2080	3565	1277	2485	2142	3022
1943	2644	11256	13614	12255	2794	2040	4338	3022	6532	2412	1812	2340	5421
1944	4288	6947	2102	2796	2073	1502	2137	1505	2865	1471	3285	2013	2749
1945	2844	1886	868	4526	2921	2735	4266	5887	3935	1529	2812	1701	2992
1946	2389	9288	10733	11256	2593	3925	2022	3586	4586	2063	1659	2265	4697
1947	4133	10277	8857	4370	1703	1946	3782	1726	4276	1906	1809	2454	3936
1948	6138	10504	4329	10105	3273	3833	3439	5164	6453	2311	1907	2600	5004
1949	3995	7538	9730	2694	2908	3898	3890	6618	4207	1749	1617	2228	4256
1950	3878	5275	3389	7333	2933	6138	3940	5017	7190	2632	1758	2354	4320
1951	9007	11851	9802	9648	3474	3373	2689	3777	3292	1627	2303	1692	5211
1952	6533	9090	9758	5338	3889	4813	4945	4884	5309	2679	1817	2479	5128
1953	3406	4383	2848	14359	7250	3541	1943	5819	6830	2568	1912	2484	4762
1954	3878	11525	12784	9106	3581	2101	3890	2394	4865	2096	1778	2390	5032
1955	3730	4976	2955	4584	1545	3002	3955	5534	6712	2443	1604	2394	3619
1956	4726	11305	15490	13710	2579	4244	4784	6053	6082	2478	1868	2517	6319
1957	[illegible]	7112	9201	2821	2916	8717	3300	3178	3597	1684	2027	1860	4317
1958	[illegible]	5515	9126	7861	6271	1787	2850	3244	5282	2035	1688	2392	4330
Mean	[illegible]	6732	6261	6391	3160	3363	3055	3498	4697	1965	2235	2121	3916

Table 323 Modified Mean Discharges, in CFS, Coast Fork Willamette River near Goshen, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1112	211	177	
1929	128	250	1119	1743	1688	1766	2485	572	856	566	778	177	1011
1930	175	70	2499	1258	3738	606	411	557	556	1153	247	161	953
1931	132	810	564	1053	512	1727	1842	321	300	841	231	130	705
1932	338	1605	2769	3153	2183	4241	1963	1219	651	175	1133	175	1634
1933	262	1415	2314	4113	2903	2506	1344	1922	1190	175	1208	235	1632
1934	260	231	2004	2853	545	565	535	442	300	472	240	50	708
1935	417	2705	3994	3413	1543	1926	2084	551	356	247	918	182	1528
1936	224	705	1029	6293	2153	1266	1142	1027	490	312	1049	175	1322
1937	175	76	428	633	2723	3386	4386	1208	1626	259	1285	216	1367
1938	507	3295	3014	2753	4133	4526	2142	816	300	614	583	176	1905
1939	186	1086	1324	1583	3083	3516	418	339	300	609	226	782	1071
1940	217	118	1134	1128	3903	2126	713	386	300	801	219	180	935
1941	198	1494	2134	2083	579	475	477	533	590	1247	326	323	872
1942	259	2605	4454	1933	1813	796	413	1581	981	505	1068	194	1383
1943	187	3869	8464	5483	3353	1156	1922	552	1444	189	1301	212	2344
1944	639	1185	594	1033	1553	946	1704	407	300	1067	236	182	820
1945	114	395	384	1783	3268	3116	2884	1676	524	789	562	188	1307
1946	192	3635	4604	4303	2063	3096	657	440	324	183	1013	191	1725
1947	486	3355	3204	1863	2013	2136	1912	329	361	240	1243	247	1449
1948	1939	3305	1804	5263	3753	2576	1966	1470	713	175	1280	301	2045
1949	352	1615	4569	953	4653	2246	901	1567	300	202	958	183	1542
1950	316	722	1764	5393	4768	4216	1505	1049	627	175	1158	181	1823
1951	3757	4717	3617	5722	3781	2834	622	583	340	193	863	178	2267
1952	1194	2629	5686	3399	4099	2653	1236	509	675	291	1238	199	1984
1953	181	150	1744	6703	4587	2509	1028	2463	1329	175	1252	225	1862
1954	438	3627	5492	5772	3150	1009	1478	310	417	175	1181	238	1941
1955	276	439	1573	2454	1114	2824	3391	1455	589	175	1250	237	1315
1956	599	3415	10424	6533	2623	3356	1679	1328	788	189	1293	176	2700
1957	1269	1295	2974	1173	3608	4641	1298	606	331	278	1016	175	1555
1958	355	590	4939	3813	5228	1136	1454	300	525	175	1110	185	1651
Mean	526	1713	3020	3188	2837	2329	1533	884	613	421	882	195	1512

Table 324 Modified Mean Discharges, in CFS, McKenzie River near Coburg, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										2776	3293	1950	
1929	2250	3105	4688	7097	4816	4758	8489	6886	5570	3576	2213	1786	4603
1930	2385	2321	6488	2977	9833	4723	3517	3910	3177	2945	2275	1752	3858
1931	1897	2124	2828	2857	3255	3554	11609	3452	3231	3042	2230	1714	3483
1932	2563	5124	6387	10847	6130	14468	9193	7201	6067	3198	3023	2147	6362
1933	2629	5056	5988	11067	8623	8158	3551	7241	10976	4505	3597	2559	6162
1934	3219	3571	9608	10322	4743	3615	6032	2385	2442	2831	2304	1628	4391
1935	2153	6843	10608	8922	6523	7041	6896	5748	3193	3466	2412	2092	5491
1936	2541	3101	2765	13860	6037	6991	6745	6445	4798	3404	2419	1968	5089
1937	2349	2341	2269	2727	8528	6873	12366	8578	8072	4019	3228	2232	5298
1938	2979	8946	10848	11107	9659	11253	8817	7198	3836	3378	2340	1935	6858
1939	2546	4936	5468	5932	7814	6499	4910	3890	3067	3253	2282	1861	4371
1940	2168	2488	3423	4407	8453	9064	5550	3489	2200	2731	2204	1841	4001
1941	1867	3264	4853	6572	3638	2700	2892	3170	2435	2688	1996	1970	3170
1942	1964	5633	10538	6542	6455	4211	3227	4372	4747	3537	1983	1886	4591
1943	1856	6397	15253	17827	10363	5028	9697	5926	6851	4099	3569	2400	7439
1944	3694	5631	3823	3902	4029	3866	4289	3396	2463	2811	2095	1837	3486
1945	1837	2094	1996	6262	9344	6574	7251	7738	3509	3178	2229	1864	4489
1946	2177	7707	11423	11992	6039	7834	4861	5353	4376	3031	3056	2159	5834
1947	3590	9141	12473	6692	6465	5769	6937	3261	3951	3028	2897	2313	5543
1948	6799	10021	6068	12362	7942	6323	6265	7431	5415	3234	3395	2563	6485
1949	3590	6466	11503	3897	9254	6969	6167	9797	4469	3296	2990	2397	5899
1950	3125	4546	5423	8527	10354	11604	7574	7286	7343	3883	3670	2672	6334
1951	7569	13071	11253	13361	10254	6945	6346	6254	3235	3569	2616	2235	7225
1952	6545	7703	11632	6531	9534	6852	7920	6791	5055	3850	3601	2507	6543
1953	[illegible]	2823	3908	18021	13613	6702	5226	7751	6523	3942	3754	2483	6459
1954	3274	9379	14482	10701	9813	5386	6873	4322	5010	3541	3699	2834	6609
1955	3568	4136	4777	6622	4261	6088	8226	6954	7458	4276	3660	2656	5223
1956	4620	11451	20703	14222	6117	8114	8148	8804	6408	3805	3809	2708	8242
1957	4470	5641	9863	4477	7184	12336	6597	4978	3469	3497	2531	2152	5599
1958	3090	3746	12343	11222	12224	5237	6916	5066	4171	2969	3109	2332	6035
Mean	3236	5626	8122	8726	7709	6854	6769	5835	4783	3419	2839	2183	5508

Table 325 Modified Mean Discharges, in CFS, Long Tom River at Monroe, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										50	50	1197	
1929	71	141	869	1492	364	178	440	164	50	50	50	1210	423
1930	74	50	1822	690	1773	236	131	104	50	50	50	893	494
1931	85	151	204	906	241	378	655	70	50	50	50	1102	328
1932	91	837	2022	2502	753	992	488	321	54	50	50	1221	782
1933	71	182	1592	2992	1603	962	214	446	144	50	50	1277	799
1934	85	78	2209	1900	208	178	188	69	50	50	50	427	458
1935	106	1400	2270	2591	361	1099	240	145	50	50	50	1143	792
1936	78	132	469	4260	903	334	177	114	50	50	50	1179	650
1937	65	40	78	487	3265	566	1964	317	337	50	50	1318	711
1938	105	1982	2722	2334	2644	2625	385	134	50	50	50	1108	1182
1939	73	216	693	1045	1650	468	96	62	50	50	50	809	438
1940	66	42	358	1007	2492	1124	338	239	50	50	50	1110	577
1941	89	373	1279	1696	279	174	145	92	50	50	50	640	410
1942	81	744	3170	1692	1298	167	104	132	65	50	50	807	697
1943	119	1920	4202	3837	1468	277	909	253	103	50	50	1295	1207
1944	229	400	747	877	388	183	244	125	50	50	50	987	361
1945	68	205	292	987	1618	1442	619	375	56	50	50	1233	583
1946	80	1390	2657	2557	1203	1197	201	100	50	50	50	1145	890
1947	126	1410	1532	847	1068	802	665	115	93	50	50	1320	673
1948	984	1105	867	3267	1723	932	694	663	139	50	50	1356	986
1949	105	655	2552	832	3788	492	151	267	50	50	50	1201	849
1950	81	265	917	4252	2718	1587	334	176	75	50	50	1182	974
1951	1170	3165	2082	3712	1748	1267	136	105	50	50	50	1068	1217
1952	270	1055	3062	2707	1703	312	151	50	90	50	50	1227	894
1953	68	50	647	4127	1816	847	223	692	251	50	50	1315	845
1954	129	900	2702	4347	2068	587	658	166	101	50	50	1320	1090
1955	110	365	1122	1552	266	702	1518	343	76	50	50	1296	621
1956	240	1550	6652	4837	1718	1537	171	196	65	50	50	1342	1534
1957	255	220	867	727	1413	2337	348	293	70	50	50	1288	660
1958	110	125	2622	2762	3463	477	501	246	127	50	50	1302	986
Mean	176	705	1776	2261	1533	815	431	215	85	50	50	1137	770

Table 326 Observed Mean Discharges, in CFS, Marys River near Philomath, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										20	9	12	
1929	28	150	500	690	380	895	510	270	106	37	20	10	300
1930	12	10	810	405	1687	368	110	150	66	27	16	12	306
1931	27	180	275	640	319	868	520	70	43	27	13	11	249
1932	40	370	750	1135	663	2316	505	270	90	37	20	11	517
1933	42	625	890	1140	785	947	425	525	301	89	25	35	486
1934	49	130	1525	1370	313	553	170	95	34	21	14	10	357
1935	134	750	1095	935	933	589	345	175	53	32	15	10	422
1936	28	125	360	1870	822	579	270	260	99	46	21	15	375
1937	12	11	300	265	1074	1037	1250	425	262	76	29	16	396
1938	54	830	1230	1200	1184	1342	555	195	47	24	15	11	557
1939	22	310	720	735	1227	1000	190	80	84	39	18	13	370
1940	35	20	575	540	1595	742	200	115	30	18	9	14	324
1941	35	264	606	835	322	190	217	206	72	26	15	52	237
1942	43	346	1338	685	1025	250	166	203	117	51	21	14	352
1943	18	956	1610	1309	1361	512	717	172	104	40	24	16	565
1944	119	198	510	533	478	371	434	166	83	28	12	11	245
1945	15	81	157	663	1122	1070	615	396	121	41	19	23	356
1946	19	782	1248	1346	1130	869	280	107	57	32	16	15	489
1947	72	774	1297	555	978	614	458	104	109	45	28	24	418
1948	568	831	511	1465	1194	824	701	475	125	49	30	21	564
1949	37	424	1675	460	2398	508	217	278	72	30	14	15	499
1950	26	203	736	1953	1934	1234	447	170	75	27	14	10	562
1951	322	1385	1338	2101	1057	1131	272	222	74	23	11	10	662
1952	291	692	1599	1214	1227	707	251	112	61	29	11	8	516
1953	8	22	269	2188	1233	842	352	349	167	55	30	19	458
1954	55	617	1668	1849	1627	647	615	129	100	49	28	29	613
1955	59	347	707	911	644	988	999	276	96	48	19	21	425
1956	135	1048	2344	2375	1151	1359	436	130	63	23	13	12	759
1957	60	120	699	389	850	1196	487	210	92	30	14	9	344
1958	26	93	1122	1086	1875	534	617	179	75	20	9	12	462
Mean	80	423	949	1095	1086	839	444	210	96	37	18	16	441

Table 327 Modified Mean Discharges, in CFS, Calapooia River at Holley, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										58	40	30	
1929	55	139	354	338	271	770	680	448	231	81	42	22	286
1930	25	10	633	177	1201	410	170	245	142	59	35	25	261
1931	54	171	166	310	227	745	685	86	92	59	29	23	221
1932	80	352	581	606	472	2365	675	448	196	81	43	24	494
1933	85	648	707	608	559	810	595	804	654	192	54	77	483
1934	95	120	1354	761	223	550	280	136	74	46	30	22	308
1935	225	792	900	485	664	570	510	287	115	69	32	22	389
1936	55	173	275	1591	625	572	457	419	215	82	38	36	379
1937	22	19	219	156	807	963	1276	604	534	133	53	38	398
1938	106	1016	1065	923	880	1220	757	323	97	44	26	25	538
1939	43	392	590	522	911	922	328	121	181	69	33	31	342
1940	68	44	463	363	1152	713	346	197	66	35	21	34	289
1941	63	480	522	696	258	190	194	272	182	77	44	117	258
1942	145	610	1220	556	698	398	207	346	262	111	50	31	385
1943	43	1278	1862	1142	962	447	720	250	336	111	61	36	601
1944	199	340	314	324	461	368	515	204	121	54	30	33	246
1945	30	143	144	598	1123	892	882	591	162	57	33	41	386
1946	30	981	1254	1075	736	926	392	193	107	61	34	33	484
1947	195	927	1136	544	682	558	613	134	266	112	62	47	437
1948	679	869	491	1173	961	645	663	540	183	79	51	67	532
1949	144	558	1265	301	1365	753	451	554	102	47	29	32	461
1950	94	306	550	1026	1303	1170	711	500	292	87	45	35	505
1951	322	1385	1338	2101	1057	1131	272	222	74	23	11	10	662
1952	291	692	1599	1214	1227	707	251	112	61	29	11	8	516
1953	824	22	269	2188	1233	842	352	349	167	55	30	19	458
1954	55	617	1688	1859	1627	647	615	129	100	49	28	29	613
1955	59	347	707	911	644	988	999	276	96	48	19	21	425
1956	135	1048	2344	2375	1151	1359	436	130	63	23	13	12	759
1957	60	120	699	1389	850	1196	487	210	92	30	14	9	344
1958	26	93	1122	1086	1875	534	617	179	75	20	9	12	462
Mean	144	490	861	913	873	810	538	310	178	67	34	32	438

Table 328 Modified Mean Discharges, in CFS, Willamette River at Albany, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										5084	5086	5000	
1929	5000	8376	10577	17876	11847	12986	17262	10354	9884	5000	5000	5000	9930
1930	5345	5985	19684	10039	26392	9425	6639	6889	6694	5190	5177	5000	9371
1931	4393	5315	6430	10014	7239	12133	19627	5293	6206	5108	5000	5000	7646
1932	4334	11879	18484	27677	15223	30980	18612	15431	12759	5023	5362	5644	14283
1933	6664	16164	19238	31596	21933	19593	12056	15930	23191	7329	6191	6611	15541
1934	7381	9119	26120	29304	8209	7871	9391	5000	5000	5165	5044	3171	10064
1935	4644	19338	31285	26944	13830	16329	13137	10360	8365	5000	5137	5000	13280
1936	6041	9349	8767	45086	16167	13890	11095	11639	9461	5000	5107	5029	12219
1937	5860	6745	5961	6379	25321	19651	29347	15880	18174	6313	5786	6096	12626
1938	7817	29426	30285	30149	27256	30523	18299	13274	7944	5192	5201	5000	17530
1939	5534	13789	14305	15786	21952	18398	7827	6033	6727	5103	5241	5000	10474
1940	5000	6482	10329	11240	24816	19967	9525	6106	5046	5256	5177	5000	9495
1941	5000	10334	16175	19029	7611	5788	5903	5909	5285	5202	5070	4972	8023
1942	3831	15971	36275	19334	16597	8339	5857	9196	9581	5000	5113	5000	11674
1943	5000	29001	52491	49748	23686	10398	20592	10460	15243	6347	6265	6231	19621
1944	9507	15391	9140	11184	11665	8041	11008	6439	5804	5068	5182	5000	8619
1945	5000	5000	4365	16309	24592	20634	19300	19070	9157	5339	5220	5000	11582
1946	5000	24449	35150	39864	17065	23353	9433	9771	9446	5000	5162	5611	15775
1947	8581	26851	33800	16584	17355	14413	17652	6344	9197	5000	5619	6097	13957
1948	19365	33231	18925	40769	21105	19063	16711	17537	13785	5754	6173	6711	18260
1949	8373	18481	37550	11439	31635	18411	12883	20662	9561	5000	5146	5845	15415
1950	7491	10746	14390	37069	31762	30498	16244	15297	16819	6981	6298	6361	16662
1951	20859	48633	35456	46944	29622	21313	11693	12440	7524	5000	5156	5000	20803
1952	14818	21341	39215	23604	26492	17368	15550	12200	10155	6767	5976	6144	16633
1953	6492	7571	9380	52524	34622	17183	9922	19047	16050	6116	6263	6311	15956
1954	7812	26926	45485	39434	26642	11878	14996	8135	10894	5296	5964	6578	17503
1955	7749	11291	12655	21584	10459	16747	24150	15869	15365	6430	5707	6259	12855
1956	10585	32636	71659	56273	19569	24236	17822	17948	14607	6403	6460	6743	23744
1957	10758	16381	28020	12729	20397	38716	15243	11147	7940	5000	5000	5256	14715
1958	7776	10761	34935	34454	39212	14192	15511	11177	11439	5030	5408	6357	16354
Mean	7733	16897	25549	27029	21007	17842	14441	11692	10576	5513	5486	5567	14111

Table 329 Modified Mean Discharges, in CFS, North Santiam River at Niagara, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1177	995	1084	
1929	2096	3208	1730	1948	1554	2056	1817	1000	1495	1301	1372	1445	1752
1930	1561	1776	2630	1761	1801	1533	1501	1000	1000	1032	1112	1575	1524
1931	1760	1716	1110	1640	1260	1908	1569	1000	1015	999	1482	1623	1424
1932	1832	2035	2030	2044	1975	2106	2684	3710	2586	1440	1103	1407	2079
1933	1857	4998	2230	2420	1980	1991	1000	1563	5162	2036	1266	1495	2330
1934	2395	2998	5630	4410	1000	1000	1000	1000	1093	1119	1167	1575	2032
1935	750	4475	3540	1960	1000	1000	1000	2483	1828	1248	1079	1058	1785
1936	2031	2723	1871	4129	1919	1861	1000	1283	1708	1193	1073	1411	1850
1937	1617	2253	1761	660	1340	2019	1646	2557	3516	1524	1367	1426	1807
1938	1818	5378	3580	3860	1891	1000	1745	3006	1645	1171	1142	1415	2304
1939	1693	3280	2481	1917	1909	1760	1000	1056	1343	1114	1097	1419	1672
1940	1599	2309	2107	1717	1958	2098	1000	1129	1194	1115	1117	815	1513
1941	1362	3724	1985	2428	1000	1000	1000	1000	1000	1051	1092	750	1450
1942	750	3314	4385	1913	1000	1000	1000	1000	1000	1099	1091	1044	1550
1943	1936	7023	5721	3564	1408	1639	3618	2493	2658	1831	1330	1303	2877
1944	2749	3640	1755	1536	1000	1000	1000	1000	1000	951	1098	818	1462
1945	1013	2823	955	2462	1964	1164	1908	3734	1361	1047	1097	1009	1711
1946	1918	4338	4545	4174	1000	1000	1311	3118	2298	1559	1146	1240	2304
1947	2772	5718	5650	2593	1000	1144	1467	1333	1587	1264	1094	1223	2237
1948	4845	5086	1939	4550	1000	1000	1805	3705	2857	1498	1249	1404	2578
1949	2635	4215	3227	1057	1000	1790	3158	5478	2403	1497	1219	1309	2416
1950	2483	3839	2096	2583	1817	3047	2456	3748	4186	2028	1334	1377	2583
1951	4101	6814	4351	3829	2067	1000	1983	2607	1486	1247	1206	1172	2655
1952	3654	4212	3231	1541	1242	1140	2981	3421	2173	1673	1223	1278	2314
1953	2014	2386	1371	7878	2816	1159	1348	3021	2568	1703	1271	1275	2401
1954	2363	5031	5837	3415	2077	1388	2527	2439	2666	1722	1297	1506	2689
1955	2733	3476	2032	1803	1000	1000	1000	3058	4493	2175	1305	1360	2120
1956	4111	6809	7038	5158	1000	1000	1954	3839	2844	1684	1255	1413	3175
1957	2656	3656	4078	1210	1018	3435	2091	2358	1459	1212	1082	1206	2122
1958	2218	3138	4546	4140	2827	1000	2132	2419	1729	1303	1148	1291	2324
Mean	2244	3876	3181	2810	1561	1508	1723	2352	2112	1387	1189	1281	2102

Table 330 Modified Mean Discharges, in CFS, South Santiam River at Waterloo, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Annual
1928										634	634	600	
1929	1472	3303	2623	2932	2149	3753	3325	2235	2189	651	996	1071	2225
1930	1501	1379	4257	2117	4652	2147	1730	1535	1079	696	744	1154	1916
1931	1830	2350	1393	2692	1435	3857	3351	842	800	651	1159	1444	1817
1932	954	3042	3473	4821	2814	7644	4056	3576	1822	666	600	1027	2874
1933	1748	6743	4823	5242	3342	3691	2288	5472	5850	1271	615	1261	3529
1934	2214	3146	8338	6528	1110	1859	1640	1145	800	729	751	1250	2459
1935	1138	6750	5878	4207	2359	2318	2966	2224	955	600	665	600	2555
1936	1798	3088	2172	9165	3015	2841	2098	2000	1413	690	650	1065	2499
1937	1474	1771	2032	1581	3386	4027	4812	4668	4041	992	1015	1097	2575
1938	1830	8625	6190	6076	3727	4024	4692	2927	934	600	697	1016	3445
1939	1535	4101	3984	3208	3653	3572	2000	1052	1256	631	729	1032	2229
1940	1621	2129	3448	2589	5157	3737	1474	1117	800	715	714	600	2008
1941	843	5246	3331	4139	1129	952	963	1442	1087	715	736	616	1767
1942	1141	5133	7282	3532	2443	1558	1078	1696	1336	623	667	648	2261
1943	1754	11159	11520	7110	4433	2384	4445	1834	2640	906	681	756	4135
1944	3090	4222	2001	1961	1774	1652	2073	1252	907	634	727	600	1741
1945	1114	3073	1071	4368	4800	3323	4021	4494	1048	600	710	600	2435
1946	1667	7548	7784	6713	2593	3936	2189	2056	1337	740	600	720	3157
1947	3119	8127	8621	3729	1966	2448	3079	905	1550	897	694	875	3001
1948	6406	8045	3385	7445	3817	2637	3308	3778	1706	708	629	989	3571
1949	2751	5528	7350	1540	5339	3800	3123	4856	1141	600	600	615	3103
1950	2444	4403	3708	5588	5619	6142	3753	3897	3343	1041	631	775	3445
1951	5986	9766	6123	8417	4246	2923	2361	2468	800	600	668	600	3746
1952	4926	5923	6658	3113	4297	3141	3396	2573	1643	1151	600	722	3178
1953	1652	2057	2311	11734	6868	3005	2349	4247	2612	809	633	766	3253
1954	2230	7631	10233	7272	4242	1943	3444	1065	2174	848	682	1158	3577
1955	2719	3853	3782	3733	1911	2552	4660	4540	3512	1375	682	882	2850
1956	4288	9692	12705	9458	2029	3188	4638	3786	2189	787	610	735	4509
1957	3079	4368	6971	1820	3733	6529	2860	1746	945	600	600	670	2827
1958	2088	3592	9295	6803	5676	1575	3954	1257	1328	668	600	709	3129
Mean	2347	5197	5425	4961	3487	3239	2931	2556	1781	773	703	868	2856

Table 331 Modified Mean Discharges, in CFS, Santiam River at Jefferson, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Annual
1928										1829	1460	1836	
1929	4188	8364	7225	7971	5588	10439	9160	6466	5249	2098	2219	2606	5964
1930	3231	3302	11429	5618	14519	6120	4808	4346	2664	1642	1660	2819	5180
1931	4030	5469	4145	7363	4655	11465	9437	2781	2227	1565	2421	3153	4892
1932	3555	7600	9225	11796	7874	20050	11368	10758	6183	2312	1573	2528	7902
1933	4291	16934	11775	13013	8747	11142	7805	11817	16056	4088	1852	3644	9263
1934	5713	7684	23275	18263	3750	6675	4882	3318	2145	1657	1681	2887	6827
1935	3717	1656[illegible]	15575	10213	7600	6973	7265	7042	3482	1921	1516	1723	6966
1936	4302	70[illegible]	6052	23061	8583	8733	6734	6297	4191	1968	1503	2562	6756
1937	3228	4130	6059	3169	8245	11922	13320	11602	10738	2743	2264	2675	6674
1938	4690	20471	16150	16413	9662	11175	11737	8698	3136	1643	1594	2512	8990
1939	3521	10042	10620	8512	10208	10784	5869	3338	3526	1732	1614	2550	6026
1940	3736	4911	9595	6863	15767	11304	5265	3863	2086	1554	1563	1549	5671
1941	2835	12774	9020	10473	3725	3135	3000	4390	2924	1628	1640	2224	4814
1942	3044	12104	18520	8833	7692	4810	3561	5282	3940	2044	1587	1721	6095
1943	3879	25749	25192	17898	13127	6509	13279	5990	6683	2923	1860	2147	10436
1944	7150	9844	5865	5638	5685	4896	6115	3690	2548	1382	1538	1518	4656
1945	2372	7074	3200	10863	12437	9094	9836	12298	3147	1441	1580	1826	6264
1946	3833	16929	18400	17153	7819	10374	5959	6621	4371	2433	1495	2065	8121
1947	7046	19084	21960	10433	7185	6738	8043	2960	4607	2481	1797	2389	7893
1948	15569	19339	8570	19513	10060	7689	8955	10619	5486	2224	1814	2717	9379
1949	6484	13114	18300	4333	15788	9715	9179	14509	4183	2031	1663	2150	8454
1950	5871	10559	10460	15658	15992	16274	10531	10883	9402	3359	1888	2366	9437
1951	14542	25009	17095	21893	12857	8439	7004	7273	2549	1637	1654	1833	10148
1952	11763	13864	16735	8103	11647	8439	9298	7760	5040	3584	1658	2052	8328
1953	3817	4634	5605	31930	18122	8179	5981	10688	7285	2591	1824	2171	8569
1954	5225	17869	26225	18333	12797	6294	10055	4568	6839	3147	2001	3049	9700
1955	6445	9514	9845	9733	6055	7658	11415	11117	9926	4166	1872	2369	7509
1956	10857	23549	32157	24101	6485	9748	10266	10432	6599	2579	1765	2134	11722
1957	6859	10464	16175	5108	9712	17094	8206	5907	3274	1813	1551	1816	7331
1958	4852	8109	21480	17523	14897	4843	10120	4853	3979	1999	1547	2022	8018
Mean	5681	12404	13864	12992	9909	9224	8282	7339	5149	2279	1740	2326	7596

Table 332 Observed Mean Discharges, in CFS, Luckiamute River near Suver, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										178	160	160	
1929	90	1200	1160	1635	960	800	2100	340	240	104	33	30	724
1930	60	50	1240	1010	3850	925	740	650	186	48	33	33	883
1931	55	230	370	1525	875	1510	1600	250	172	72	49	42	563
1932	245	1520	1650	2650	1580	2810	1260	310	100	43	30	25	1019
1933	80	1250	3100	3040	2360	2160	780	1660	412	76	39	150	1259
1934	325	500	5250	3150	655	965	570	270	80	33	28	26	988
1935	433	2460	2300	1990	920	1706	709	269	98	54	35	36	918
1936	51	227	724	3980	1461	1157	510	521	228	90	43	35	752
1937	31	37	838	1080	2814	1425	2500	538	612	207	68	44	850
1938	131	2410	3370	2060	1935	2313	911	277	104	48	32	32	1135
1939	55	462	1030	1430	2829	1128	310	146	106	58	32	29	635
1940	95	115	1510	1210	3150	1607	710	721	126	55	32	37	781
1941	70	431	1072	1771	664	391	353	394	135	56	38	165	462
1942	148	720	2580	1324	1914	575	330	358	240	111	56	36	693
1943	46	2404	3358	2163	2674	871	1654	373	234	102	64	43	1154
1944	285	446	1173	1153	1052	789	823	326	205	70	42	34	532
1945	41	271	454	1638	2268	1794	1149	689	219	76	46	80	718
1946	44	1569	2638	2725	2129	1781	655	227	134	105	43	47	1003
1947	262	1794	2971	1276	1894	1228	744	206	275	90	66	66	900
1948	1241	1386	917	2380	2128	1573	1135	900	213	96	58	49	1004
1949	145	885	3291	870	4769	1152	470	647	150	74	43	45	1022
1950	92	786	1742	3390	3374	2581	969	353	134	57	40	34	1118
1951	562	2662	2710	3786	2101	1719	556	448	154	66	34	33	1233
1952	767	1244	2579	1805	2515	1196	600	246	123	56	27	22	928
1953	20	57	761	4627	2391	1438	675	703	346	108	60	49	932
1954	153	1283	3038	2958	3180	1234	1245	270	256	117	58	68	1143
1955	156	676	1242	1520	1202	1690	1847	563	178	103	43	64	771
1956	477	2366	3850	4727	1570	2521	898	257	124	49	28	34	1414
1957	163	309	1360	687	1530	2179	810	366	178	72	41	29	640
1958	66	277	2629	2197	3393	934	1170	359	152	52	26	35	926
Mean	224	998	2030	2192	2136	1478	956	455	197	78	42	48	903

Table 333 Modified Mean Discharges, in CFS, Willamette River at Salem, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										6000	6000	7019	
1929	9111	17505	19400	29592	22352	21038	25899	15350	15248	6083	6406	7800	16315
1930	9071	9941	33173	17548	45160	16535	12919	12161	9708	6000	6000	7811	15502
1931	8762	10765	11500	19572	13713	22891	37072	9133	8315	6000	6671	7965	13529
1932	7571	21706	31354	45626	23961	51393	30823	24670	18060	6767	6290	7896	23009
1933	11122	32039	33700	50472	34493	33018	19269	26445	37312	11007	7095	9990	25496
1934	12798	18264	59110	52372	13531	14606	16468	9974	6575	6000	6000	6000	18474
1935	8157	38574	53005	43322	23537	27338	21856	18280	12118	6457	6000	6659	22108
1936	10588	17039	16035	78657	27839	24118	17782	18191	13887	6373	6000	7616	20343
1937	9538	11446	12571	11873	41499	33209	49170	27082	28662	9091	7455	3810	20450
1938	12602	54647	54450	53917	43201	48899	30543	21702	10485	6000	6000	7352	29149
1939	9090	23891	25160	26118	37358	31033	13414	8706	9583	6000	6000	7505	16987
1940	8831	11628	21949	21338	47206	36702	16698	10649	6677	6000	6000	6444	16676
1941	7925	23453	28865	34602	13149	9913	9241	10799	8044	6000	6000	7136	13760
1942	7140	30100	62045	31477	28207	14504	10076	14644	13507	6434	6000	6641	19230
1943	9019	55315	83238	73696	41101	17417	36904	16801	21071	8349	7445	8492	31569
1944	17337	26734	17915	20097	20583	15112	19426	11134	8581	6000	6000	6343	14605
1945	7432	12884	8795	31702	42382	34618	31904	33053	12299	6000	6000	6786	19487
1946	8948	42763	57090	65202	28687	38007	16480	16557	13497	6823	6052	7511	25634
1947	15727	49134	64470	31457	31374	23936	27928	9669	13349	7016	6841	8392	24107
1948	39129	59994	29305	63702	34068	30047	27043	28356	18276	7178	7392	9318	29483
1949	15011	32164	60660	18082	54481	29716	21560	34496	13405	6361	6064	7875	24989
1950	13867	21839	27220	58742	52572	53808	30453	26955	26181	9740	7306	7938	28051
1951	31641	78646	56971	72657	45417	33887	19595	19908	9748	6052	6000	6618	32260
1952	27026	37324	63410	37452	45877	29128	27016	21490	15320	10702	7003	8111	27487
1953	10379	12309	17160	94329	60312	29893	18736	31825	24820	8727	7732	8667	27073
1954	13792	46899	79035	64277	48102	21107	26574	12528	17068	8018	7480	9846	29559
1955	14773	21779	23225	34112	17712	24871	37088	26171	23576	9866	7064	8603	20736
1956	21247	58309	97010	89049	30167	38058	29426	28010	20571	8499	7495	8189	36334
1957	16676	27866	44561	18652	30122	60220	25053	17266	11310	6142	6188	7071	22593
1958	12820	18625	60441	56883	63772	21135	26725	15216	14030	6385	6555	8091	25889
Mean	13571	30786	41394	44985	35397	29538	24438	19241	15376	7002	6551	7616	22991

Table 334 Observed Mean Discharges, in CFS, South Yamhill River near Whiteson, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										161	61	450	
1929	90	736	2153	2240	1393	2493	1750	929	340	100	45	34	1025
1930	45	80	3045	1153	5303	1360	570	857	260	79	44	33	1069
1931	75	607	994	2083	1313	3604	3150	198	200	80	29	34	1031
1932	160	1591	3290	3938	2608	6115	2150	821	286	77	41	30	1759
1933	120	2399	3045	3780	2415	3658	1420	1202	450	172	57	123	1570
1934	270	892	8006	4820	1106	2204	890	504	150	57	38	36	1581
1935	300	2250	3948	3227	2338	2586	1400	651	180	105	42	36	1422
1936	115	440	1201	6340	2373	2344	1160	936	305	117	48	50	1286
1937	36	62	1260	775	3267	3587	4750	1156	422	152	58	70	1300
1938	270	3889	4893	4594	3204	4734	2500	701	160	54	36	29	2089
1939	70	1021	2303	2529	3325	3360	820	287	255	90	37	40	1178
1940	105	142	2779	1603	5164	3595	1390	518	115	64	28	33	1295
1941	144	827	2108	3332	1223	699	585	684	223	63	33	189	844
1942	186	1014	5531	1891	3333	908	545	579	359	153	58	35	1207
1943	51	4084	5538	3740	4745	1473	3039	549	335	128	68	45	1961
1944	625	818	1897	2096	1852	1333	1346	446	306	85	44	37	905
1945	57	574	706	2626	4531	3906	2006	1025	265	87	45	138	1311
1946	71	3312	5084	5536	4728	3386	1351	398	207	166	53	50	2015
1947	410	3144	5070	2520	3699	1966	1214	285	486	161	72	97	1580
1948	1819	3049	2253	4940	4397	2901	2545	1736	340	127	69	80	2014
1949	296	2317	6231	1558	8890	2282	823	1144	207	99	53	55	1952
1950	178	1389	3138	6266	6223	4434	1692	577	209	84	52	49	2003
1951	971	4761	4732	7138	3857	3304	941	557	180	66	28	34	2209
1952	1298	2250	5428	3577	4680	2618	961	445	165	64	26	20	1789
1953	23	105	1698	8817	4104	2938	1275	1304	592	152	86	69	1758
1954	339	2289	5818	6603	6642	2320	2404	499	419	163	76	119	2283
1955	347	1679	2745	3767	2553	3287	3357	1013	306	167	59	113	1611
1956	1130	5010	8493	8603	3467	5860	1807	479	204	68	39	49	2944
1957	383	731	2267	1506	3530	3918	1649	645	265	104	57	35	1245
1958	135	736	5269	4370	6654	1866	2745	613	227	62	20	33	1866
Mean	337	1740	3698	3866	3764	2969	1741	725	281	105	48	60	1611

Table 335 Observed Mean Discharges, in CFS, Molalla River near Canby, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										155	61	99	
1929	141	629	1230	1280	796	1370	1640	1290	803	189	85	64	793
1930	74	68	1740	659	3030	947	641	1190	500	149	83	62	748
1931	121	519	568	1190	750	1980	2300	275	348	151	55	64	691
1932	251	1360	1880	2250	1490	3360	1850	1140	586	145	77	57	1210
1933	193	2050	1740	2160	1380	2010	1420	1670	1690	325	107	232	1250
1934	411	762	4575	2754	632	1211	960	700	237	107	72	68	1050
1935	447	1923	2276	1844	1336	1421	1401	904	301	199	78	68	1013
1936	180	376	686	3623	1356	1288	1209	1300	651	221	90	95	924
1937	65	53	720	443	1867	1971	2954	1606	1274	286	109	133	948
1938	411	3324	2796	2625	1831	2601	2022	973	254	101	68	55	1418
1939	114	873	1316	1445	1900	1846	898	398	494	170	70	75	793
1940	164	121	1588	916	2951	1975	1397	719	164	76	50	98	845
1941	303	1449	1402	1492	592	505	383	863	457	140	84	349	669
1942	475	1397	3009	1253	1796	964	614	1145	793	306	114	73	992
1943	114	3844	3888	2645	3100	1285	2194	877	780	248	134	100	1587
1944	668	740	834	916	1029	1004	1100	620	445	146	75	100	638
1945	104	472	435	1480	2245	1822	1934	2376	479	144	104	218	976
1946	142	2743	2785	2681	1949	2216	1121	795	559	291	112	116	1289
1947	587	2447	2841	1638	1607	1193	1202	324	711	297	134	136	1089
1948	2201	2618	1318	3090	2219	1737	1548	1667	571	184	124	179	1453
1949	503	1871	2816	695	4265	1871	1671	1926	403	156	87	124	1346
1950	365	1026	1948	3178	3605	2662	1733	1414	1188	287	117	114	1457
1951	1827	3749	2634	4003	2738	1915	1186	865	232	102	64	74	1610
1952	1133	1410	2390	1328	2563	1652	1406	958	721	491	103	74	1181
1953	60	94	826	5124	2906	1821	1378	1545	1162	242	145	110	1278
1954	323	2037	4043	3288	2736	1300	1711	622	1089	408	167	190	1485
1955	545	992	1454	1327	1181	1536	2292	1666	1310	441	123	172	1085
1956	1378	3447	4839	4125	1352	2250	1888	1319	790	202	115	98	1822
1957	639	882	1727	849	2016	3085	1655	1021	552	172	108	64	1059
1958	241	600	3160	2736	2974	956	2172	573	392	155	61	99	1166
Mean	473	1496	2115	2101	2006	1712	1529	1091	664	218	97	115	1135

Table 336 Observed Mean Discharges, in CFS, Pudding River at Aurora, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										95	34	60	
1929	162	605	1270	1870	1070	1100	1750	757	374	125	67	57	766
1930	69	82	1910	962	3870	1070	683	828	375	128	71	80	825
1931	123	460	573	1460	957	1650	3090	327	349	181	74	70	773
1932	205	1780	2590	3300	2010	3310	1750	744	332	123	75	60	1360
1933	161	1610	2170	3570	2260	2940	1260	1360	1100	207	97	205	1410
1934	295	700	5170	3633	864	1325	1142	696	207	102	68	62	1199
1935	355	1975	2842	2992	1535	1996	1217	551	184	124	65	72	1159
1936	136	319	668	4352	1773	1428	1002	859	489	191	69	80	948
1937	66	79	662	766	3563	2100	3239	902	730	266	97	110	1028
1938	305	3039	3904	3670	2990	3121	1668	682	216	99	55	61	1644
1939	120	889	1204	1853	2679	1702	638	242	294	124	52	65	810
1940	150	151	1679	1353	3532	2491	1477	672	158	67	50	81	980
1941	205	1110	1863	1885	832	599	456	638	337	117	73	213	695
1942	298	1138	3408	1719	2277	916	498	929	662	243	94	61	1014
1943	78	3098	4624	3768	3916	1035	2713	720	617	217	120	94	1733
1944	544	784	1130	1463	1466	1047	1120	474	283	97	54	59	708
1945	71	373	436	1517	2466	2527	1879	1623	415	116	72	143	961
1946	108	1801	2955	3488	2508	3000	1028	466	264	179	71	83	1325
1947	353	2006	3452	1572	1999	1421	1448	323	475	197	102	96	1114
1948	1774	2482	1518	3664	2311	2454	1730	1416	396	146	109	116	1509
1949	295	1508	3661	1209	5600	2067	1086	1081	250	113	67	90	1392
1950	245	700	2004	4735	4263	3310	1638	991	472	143	79	78	1542
1951	1170	4643	3239	4853	3208	2624	887	703	203	80	51	64	1803
1952	914	1497	3283	2241	3474	1905	1130	618	327	364	69	64	1318
1953	64	104	793	5576	3743	2142	1179	1171	898	183	98	92	1325
1954	327	1770	4772	3721	3375	1506	1659	418	708	282	113	158	1558
1955	391	1028	1808	1895	1255	1795	3054	1193	500	224	77	107	1109
1956	1036	3039	5704	5722	2127	3115	1630	683	365	116	71	77	1980
1957	332	756	1421	1108	1872	3945	1362	659	360	91	59	41	997
1958	153	405	2959	2982	4384	1459	2011	567	305	95	34	60	1266
Mean	350	1331	2456	2763	2606	2037	1514	776	421	158	75	90	1215

Table 337 Observed Mean Discharges, in CFS, Tualatin River at West Linn, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										101	30	25	
1929	118	436	1230	2350	1080	1120	1700	604	310	151	23	18	761
1930	36	57	847	669	3740	1450	593	552	242	69	22	16	671
1931	43	178	272	1710	1490	2150	3290	402	191	65	12	22	812
1932	133	1370	3000	5380	2480	3590	2180	703	262	118	39	9	1600
1933	36	1060	3580	5230	2880	4530	1670	1060	587	214	42	92	1750
1934	179	447	7686	5409	1642	1271	998	589	156	49	18	27	1551
1935	347	4121	4839	5085	2816	3114	1780	529	218	78	24	26	1911
1936	60	168	540	6459	2071	2731	1136	566	403	127	35	30	1197
1937	29	40	691	933	4398	3151	3642	840	422	168	59	68	1179
1938	86	2054	5411	5635	4401	4433	1794	508	180	69	36	42	2046
1939	78	415	1002	2055	4136	1731	524	175	100	33	8	18	836
1940	49	66	1595	2409	5544	3257	1552	1011	225	43	12	21	1301
1941	83	428	1862	3504	1615	740	506	411	179	40	17	91	788
1942	138	686	4599	2000	3961	1034	514	496	324	105	28	10	1143
1943	24	2520	4915	4471	5247	1173	3535	549	328	107	41	25	1887
1944	179	379	1067	1725	1896	1256	1070	496	219	42	11	13	693
1945	28	279	371	1565	3453	3755	1780	772	282	52	15	69	1020
1946	46	1677	3801	5140	4696	3235	1297	424	228	85	13	15	1707
1947	100	1615	4779	1773	4090	1899	967	245	192	56	29	15	1297
1948	859	1960	1644	4899	3172	3074	2053	1868	422	127	63	64	1682
1949	126	1176	5195	1549	7092	3290	929	653	160	52	21	24	1657
1950	77	584	2003	4950	5564	5382	2153	563	209	59	21	20	1779
1951	415	3022	4524	6445	4894	3049	1035	480	180	59	30	46	2001
1952	581	1436	5061	3111	4673	2613	1112	442	233	96	27	45	1612
1953	52	128	685	6485	4587	2246	1395	974	552	171	74	83	1437
1954	212	993	4538	5934	7444	2623	1555	436	336	153	58	136	2004
1955	208	1220	1988	3103	2468	2335	2909	1008	290	178	65	76	1313
1956	487	3360	8769	7984	2869	4825	2282	509	264	84	52	90	2643
1957	222	581	1562	1144	2133	4965	1666	621	258	79	60	45	1108
1958	119	326	2665	4181	6124	2529	2107	759	360	101	18	46	1584
Mean	172	1093	3024	3776	3755	2752	1657	651	274	94	32	42	1443

Table 338 Modified Mean Discharges, in CFS, Willamette River at Oregon City, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										5425	5225	7144	
1929	10041	21890	27825	41512	28597	28708	38178	19231	17013	5708	5691	7905	21024
1930	9466	10396	43518	23043	67440	24395	17368	16812	10933	5445	5295	7971	20173
1931	9317	13235	14340	29462	19823	35401	54046	10619	9270	5615	5971	8125	17935
1932	9081	32546	46589	67466	36346	73803	42117	28451	19080	6227	5610	7986	31274
1933	11922	42594	51330	73657	49628	52593	27208	34881	42527	10982	6520	9820	34554
1934	14813	22524	96125	76632	18621	23281	22417	12975	6855	5315	5275	6130	25913
1935	10667	55759	72055	62002	33512	40733	29600	21216	12493	5977	5215	6829	29670
1936	11268	18929	20325	98051	38444	34313	23461	22857	15817	6178	5350	7836	25235
1937	9868	11906	18101	17058	61984	46649	69174	32373	32397	9211	6920	9165	27066
1938	14087	73882	79930	70532	61211	69584	40837	25038	10850	5325	5255	7477	38666
1939	9690	28846	32750	37723	56413	41613	16733	9812	10353	5450	5220	7635	21852
1940	9601	12463	33729	30808	72101	52192	24802	14965	6857	5210	5210	6654	22882
1941	9015	29138	39255	48137	18894	13553	11960	14125	9009	5390	5310	8141	17660
1942	8715	36290	84500	41237	43542	19874	13085	18850	15832	6449	5435	6771	25047
1943	9459	74110	100202	94561	64801	24322	52858	20272	23216	8209	6985	8752	40644
1944	20157	30754	24915	28877	29398	21597	25945	13630	9531	5395	5275	6498	18497
1945	7852	15249	11560	41637	59487	51148	42608	40749	13614	5460	5360	7436	25179
1946	9523	55488	76865	88107	47132	54907	23034	19073	14407	6698	5427	7761	34034
1947	17712	61764	86640	41747	46429	32901	35082	11135	15209	6906	6361	8747	30885
1948	48194	74209	38690	86472	50273	44402	37832	36862	19911	6908	6972	9788	38375
1949	16686	41714	85040	25122	88470	42781	27809	40562	14130	5876	5444	3155	33064
1950	15087	26809	39835	85837	79782	75513	40462	31626	28251	9450	6746	3168	36879
1951	37551	102261	77556	100106	65487	49122	25094	23219	10133	5392	5465	6748	42343
1952	32196	46529	85230	51482	67117	41168	33435	24551	16520	11107	6378	3221	34910
1953	10649	12899	22530	99618	81812	42663	25855	38191	28525	8677	7347	3977	31894
1954	15407	56889	100159	90107	74332	31427	36588	14874	19878	8368	7135	10486	38803
1955	16753	28464	34265	47442	27412	36931	53632	32452	25996	10161	6589	9043	27427
1956	26642	78389	97010	101473	43497	59583	39680	31756	22242	8442	7260	8472	43694
1957	18677	31999	53965	25067	42942	82570	33631	20999	12870	6148	6041	7137	28503
1958	13628	21334	79590	76222	87411	30425	39103	18431	15459	6489	6339	3299	33143
Mean	15456	38971	55809	60034	52029	42601	33451	23346	16938	6938	5979	7237	29900

Table 339 Modified Mean Discharges, in CFS, Clackamas River at Estacada, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1120	875	821	
1929	980	1895	2235	2125	1335	2965	3395	4390	3030	1220	870	775	2101
1930	775	960	3575	1490	5425	2330	2005	2375	1430	845	695	670	1881
1931	760	1445	1500	2185	1740	4385	4980	1665	1145	870	745	730	1846
1932	970	2205	2480	3425	2455	6015	3980	3925	2515	1115	830	725	2553
1933	1015	4250	3025	3335	2045	3095	3651	4390	5830	1860	1040	1150	2890
1934	1380	1870	8930	6070	2185	3185	2470	1610	1100	890	740	690	2593
1935	1470	3985	4170	3045	3070	2690	3240	3740	2215	1225	855	765	2539
1936	925	1445	1800	6540	2585	3110	3870	3905	1960	1125	880	855	2417
1937	775	935	1955	990	1855	3445	5565	5415	4345	1555	1010	910	2396
1938	1215	4965	5370	5185	2955	4200	4850	4065	1945	1120	915	855	3137
1939	935	2110	3135	2610	2570	3760	3490	2495	1750	1055	820	770	2125
1940	905	1000	2940	1915	5540	4400	3305	1990	1000	785	700	720	2100
1941	955	2765	2710	2885	1790	1615	1505	2425	1395	825	710	965	1712
1942	1155	2505	5365	2320	3320	2220	2290	2625	1940	1075	790	660	2189
1943	730	5960	6545	4395	4995	3385	6030	3835	3275	1630	1145	974	3575
1944	1695	2220	2200	2165	2125	2140	2565	2225	1450	860	685	725	1755
1945	710	1435	1310	2845	4395	2915	3920	5175	1760	935	770	845	2251
1946	780	3605	5550	5115	3250	3490	3125	3750	2735	1350	950	835	2878
1947	1660	4490	7360	3365	3710	3215	3085	1720	1725	1150	940	870	2774
1948	3780	5060	3315	6090	4370	2775	3215	4330	2920	1385	1070	1035	3279
1949	1465	3500	4550	1655	4400	3700	4820	7445	3120	1460	1045	1320	3207
1950	1430	2665	3175	3485	5175	5240	4465	5045	5400	2055	1160	1030	3360
1951	3345	6200	5820	6025	5945	3265	4320	4160	1910	1190	1010	925	3510
1952	2680	3030	4095	2105	4090	2825	4290	4190	2610	1570	980	885	2779
1953	835	1020	1715	9405	5835	3275	3090	4020	3120	1465	1060	935	2981
1954	1100	3620	7200	4635	5980	3360	4330	3650	3540	1725	1130	1080	3446
1955	1620	2160	2695	2570	2530	2265	3590	4415	5300	2150	1135	1060	2624
1956	2595	6510	8455	6645	2575	3460	1910	5435	3480	1455	1070	925	3710
1957	1535	2280	3880	1690	3795	6005	4835	3660	1545	970	805	724	2644
1958	1000	1795	5730	4975	6260	2310	4595	2740	1630	1015	825	840	2810
Mean	1372	2929	4093	3710	3610	3368	3693	3694	2571	1264	913	875	2674

Table 340 - Modified Mean Discharges, in CFS, Willamette River at Mouth

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										6268	5934	8123	
1929	13153	28165	35280	50345	34415	38775	49530	30235	24835	8430	7720	9990	27572
1930	11700	12885	55205	28620	83980	32155	23470	23840	15265	7520	7044	9905	25966
1931	11945	18000	19205	37455	25400	48735	69700	15030	12685	7830	7815	10180	23665
1932	12050	41010	56265	81820	45200	95195	55240	39640	25735	8955	7665	10045	39902
1933	15835	57650	63805	89405	59425	65005	38015	48250	58815	15515	9085	14510	44609
1934	20025	29895	126420	98335	24675	33185	29800	17480	9585	7370	7070	7915	34313
1935	14985	70855	89395	75015	43160	50720	39625	30650	17600	8905	7220	8820	38079
1936	13905	23295	26060	122500	47695	44810	34175	33160	21550	8920	7380	10085	32794
1937	12135	14525	24935	20765	72555	59280	88160	46545	40745	12960	9340	11610	34463
1938	17830	92630	99850	88230	73215	85195	55500	34995	15175	7730	7270	9605	48935
1939	12190	36855	43095	47465	68740	53885	25735	15650	15270	8075	7145	9665	28647
1940	12220	15520	43590	37730	91335	66760	34110	20525	9295	7065	6870	8525	29461
1941	11585	38160	48625	59030	24195	17830	15935	20660	12910	7445	7080	11130	22882
1942	12470	45285	103915	49805	55015	24615	19325	26810	21920	9450	7425	8600	32053
1943	11735	95875	125205	113115	83105	33855	70540	30230	31980	11940	9625	11225	52367
1944	25355	38300	31950	35840	37145	28565	34785	19975	13810	7595	7045	8520	24074
1945	9945	19595	15600	53280	74835	62420	55710	56310	18400	7735	7255	9755	32570
1946	11840	69565	96510	107350	58745	68045	31990	28490	20935	10160	7620	9940	45932
1947	23370	77645	111540	53880	58455	42455	46150	15355	20630	9705	8570	11110	39905
1948	51170	93685	49320	106700	64815	54655	48595	49600	27485	10240	9575	12605	48554
1949	21565	53910	104060	30770	106505	54725	40595	58970	20940	9025	11095	5640	43150
1950	19895	35285	51215	101870	99130	93880	53875	45095	41475	14085	9450	5275	47440
1951	47735	125065	97145	123450	83690	60715	36145	33770	14485	7965	7630	8894	53890
1952	41850	57255	102525	60825	82655	51185	45235	34950	22865	15145	8685	4965	44011
1953	13005	15650	27810	130225	102345	53660	35730	50280	37425	12090	9855	5905	41165
1954	18725	69905	125875	108425	93295	40820	48850	23095	29515	12780	9855	13595	49562
1955	21875	35880	43850	57820	35835	45175	66780	45260	39515	15560	9280	11815	35720
1956	35575	101390	123300	125330	53035	73710	50235	45425	31295	11910	9985	10960	56015
1957	24390	40285	69265	30975	54325	103070	46905	29950	17320	8535	8065	9080	36847
1958	16740	27160	100330	93960	108190	38030	53430	25090	20245	9105	8420	5125	42152
Mean	19560	49371	70372	74011	64837	54037	44795	33480	23656	9991	8271	9499	38490

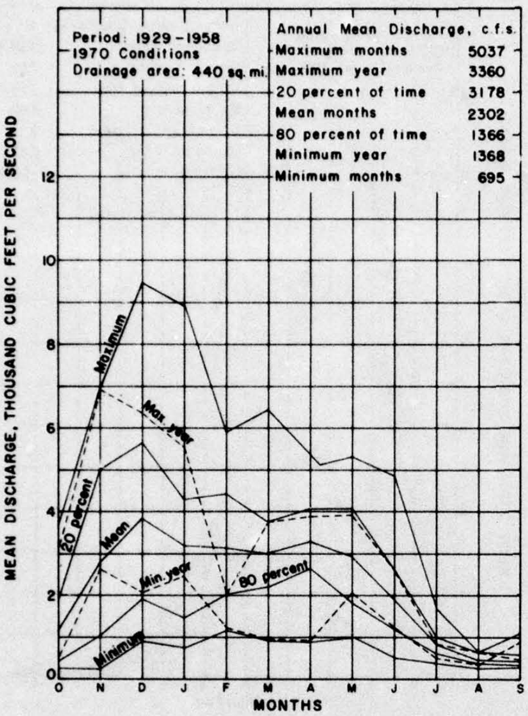


Figure 568 Monthly discharge, Sandy River Below Bull Run River near Bull Run

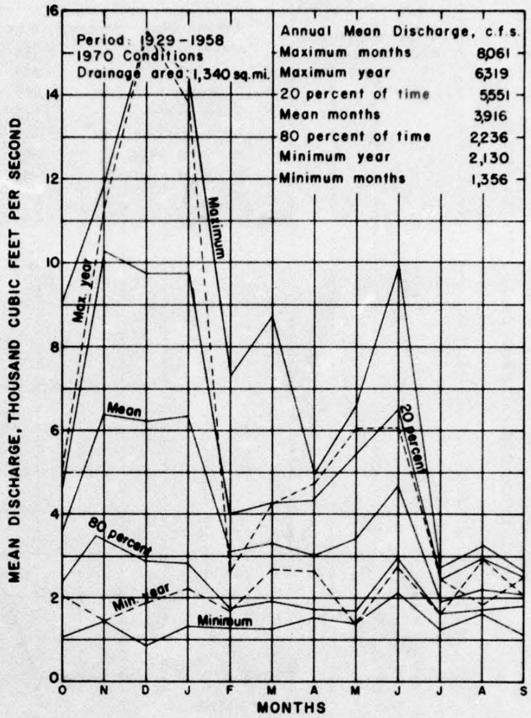


Figure 569 Monthly discharge, Middle Fork Willamette River at Jasper, Oregon

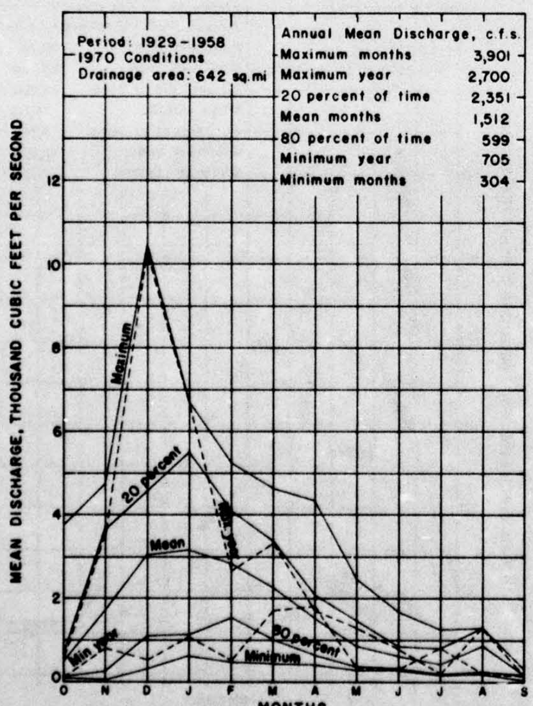


Figure 570 Monthly discharge, Coast Fk. Willamette River nr. Goshen, Oregon

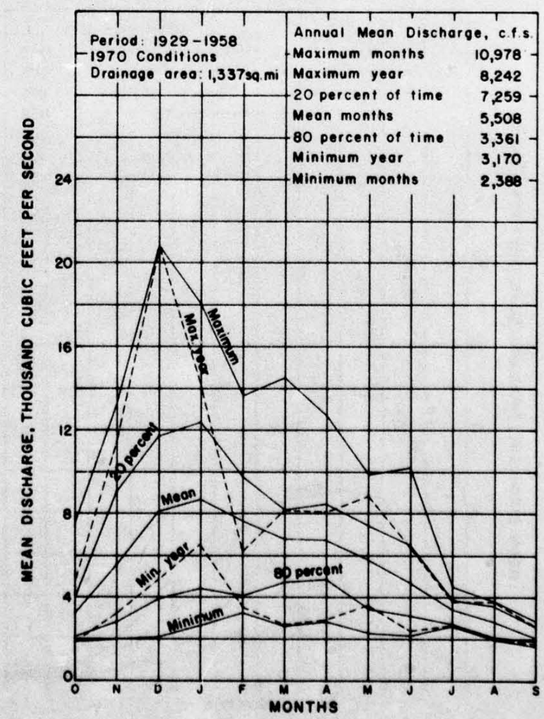


Figure 571 Monthly discharge, McKenzie River near Coburg, Oregon

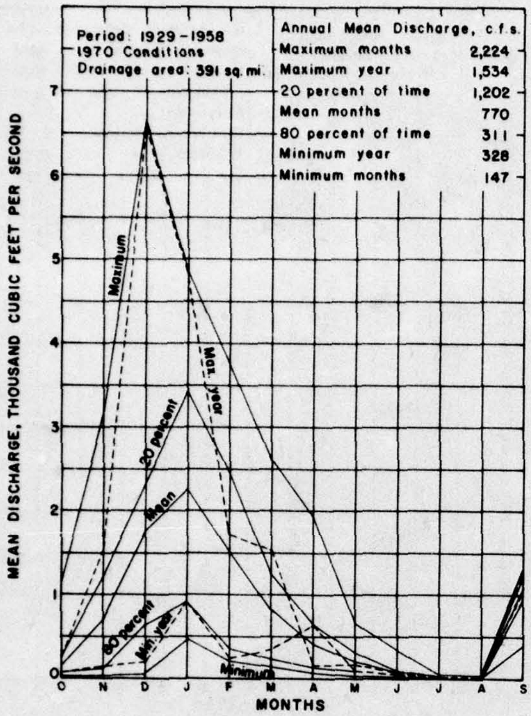


Figure 572 Monthly discharge, Long Tom River at Monroe, Oregon

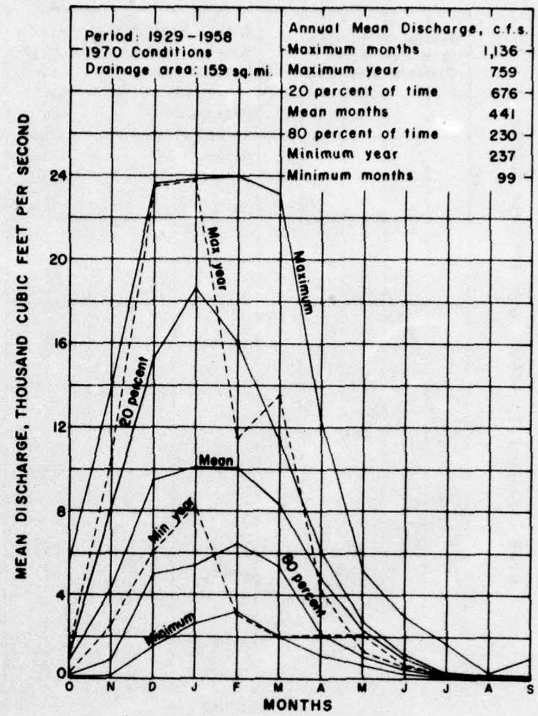


Figure 573 Monthly discharge, Mary's River near Philomath, Oregon

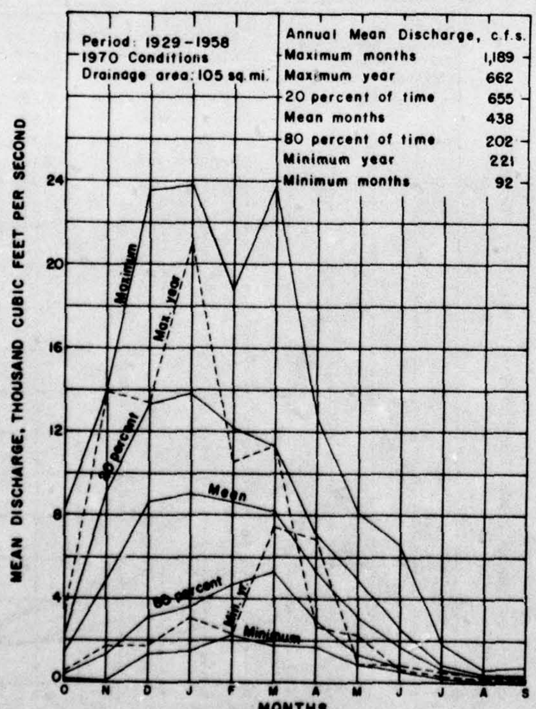


Figure 574 Monthly discharge, Calapooia River at Holley, Oregon

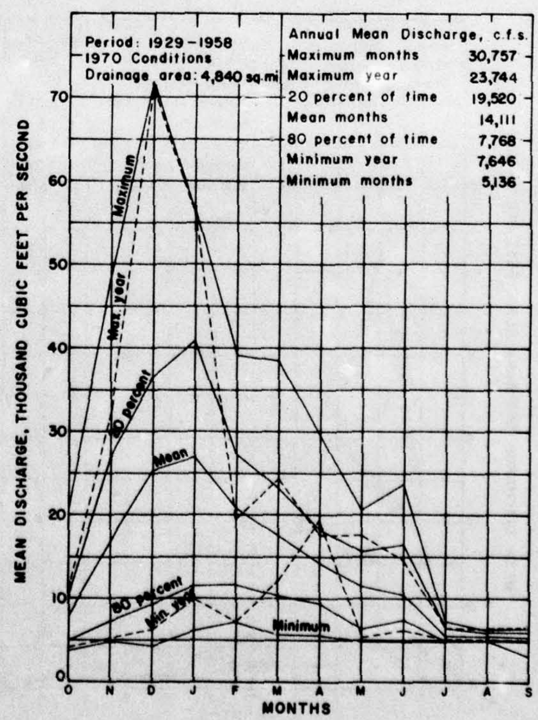


Figure 575 Monthly discharge, Willamette River at Albany, Oregon

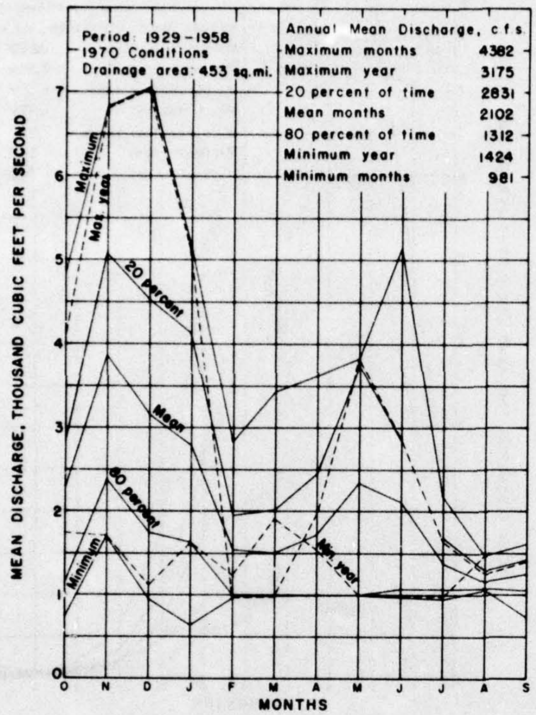


Figure 576 Monthly discharge, North Santiam River at Niagara, Oregon

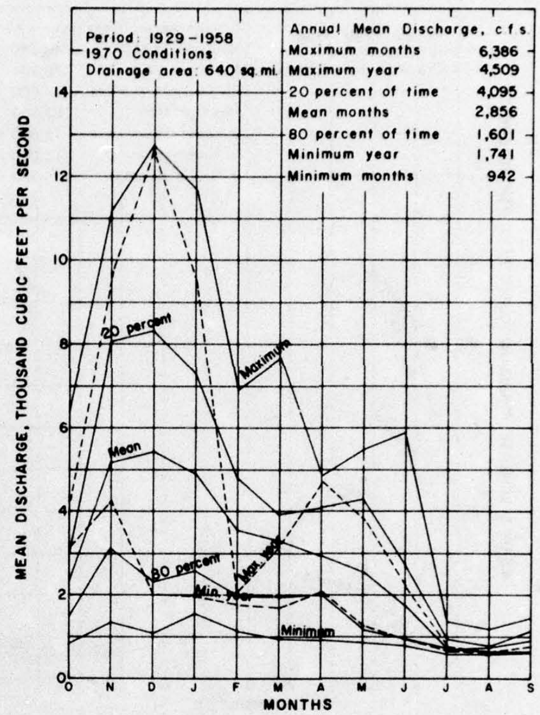


Figure 577 Monthly discharge, South Santiam River at Waterloo, Oregon

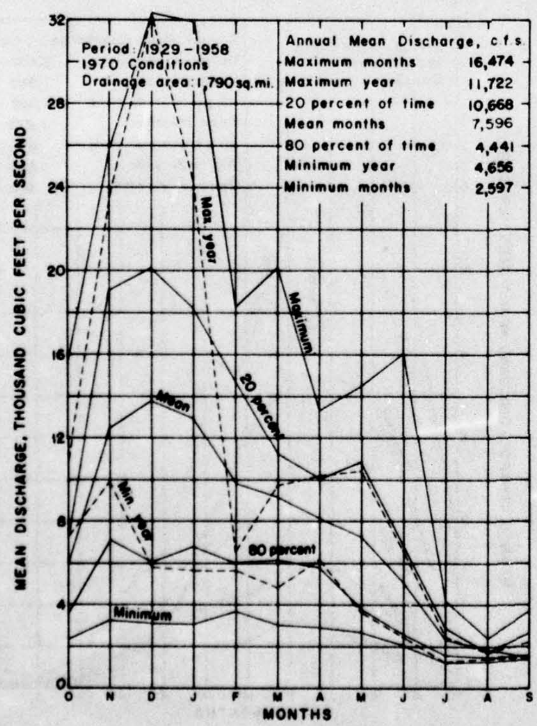


Figure 578 Monthly discharge, Santiam River at Jefferson, Oregon

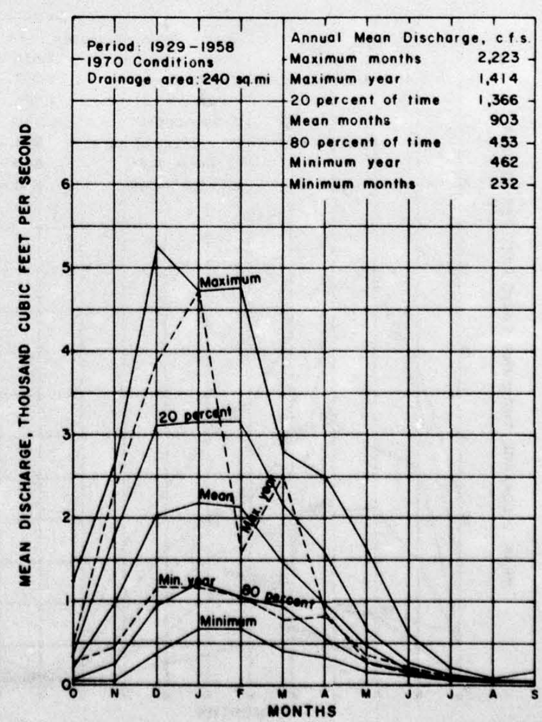


Figure 579 Monthly discharge, Luckiamute River near Suver, Oregon

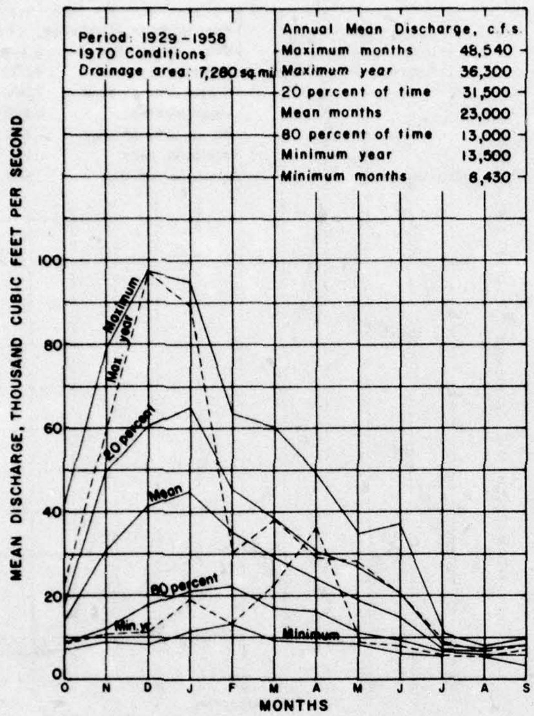


Figure 580 Monthly discharge, Willamette River at Salem, Oregon

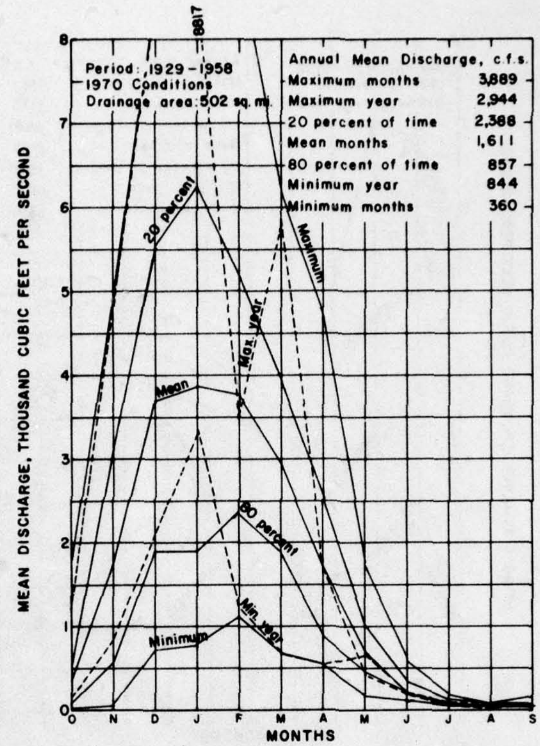


Figure 581 Monthly discharge, South Yamhill River near Whiteson, Oregon

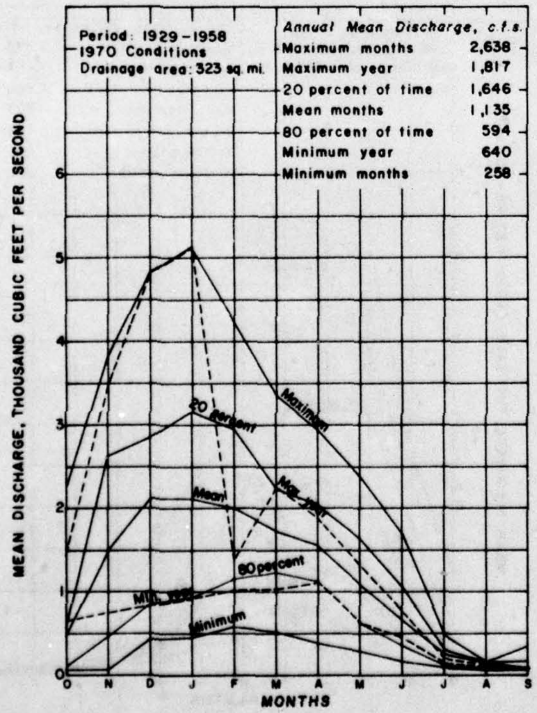


Figure 582 Monthly discharge, Molalla River near Canby, Oregon

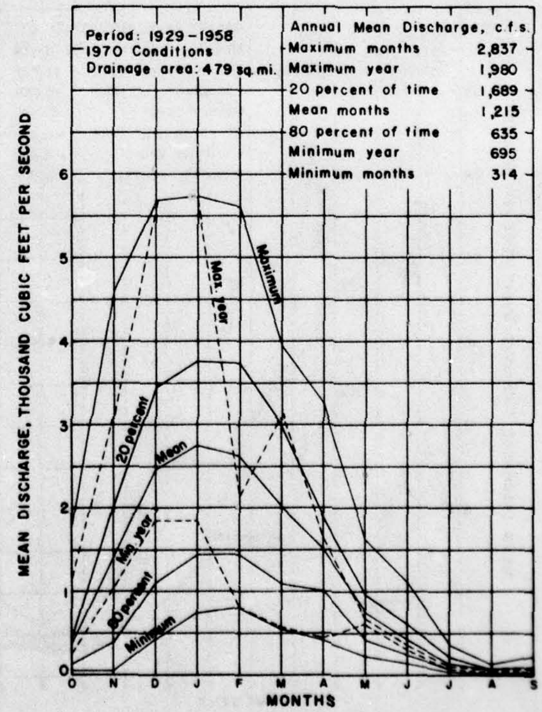


Figure 583 Monthly discharge, Pudding River at Aurora, Oregon

AD-A036 573 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

UNCLASSIFIED NL

3 OF 6
AD
A036573

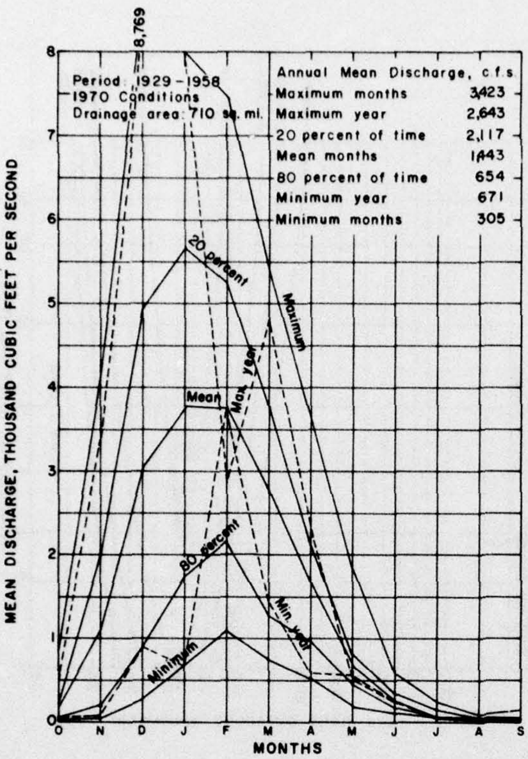


Figure 584 Monthly discharge, Tualatin River at West Linn, Oregon

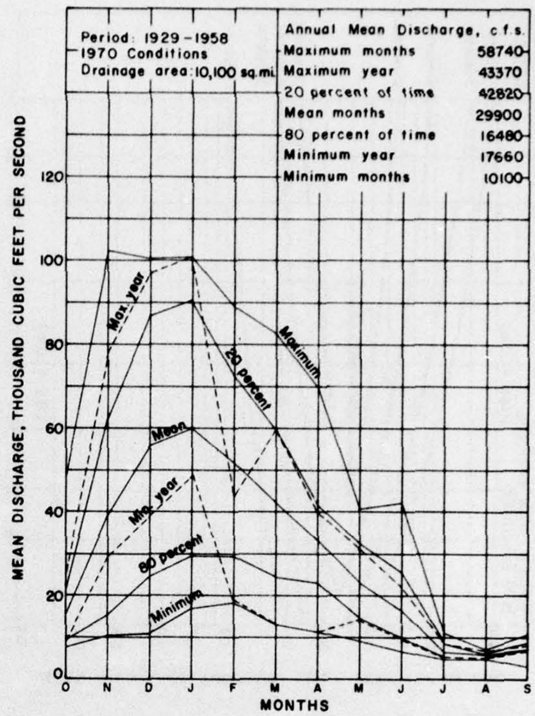


Figure 585 Monthly discharge, Willamette River at Oregon City

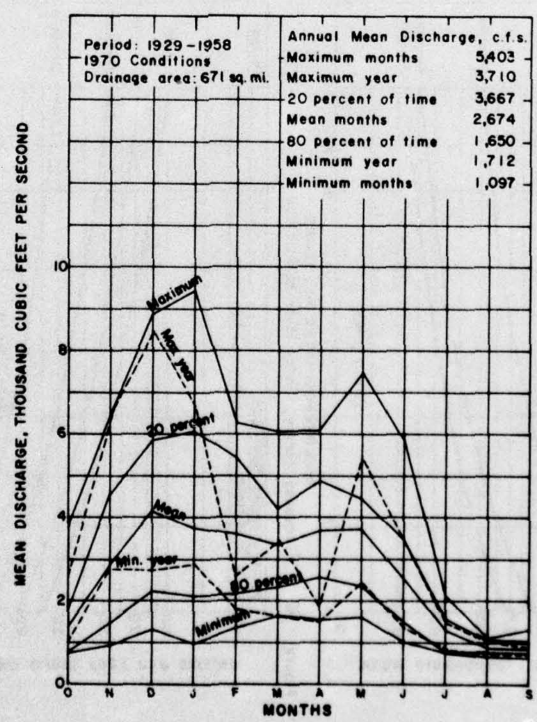


Figure 586 Monthly discharge, Clackamas River at Estacada, Oregon

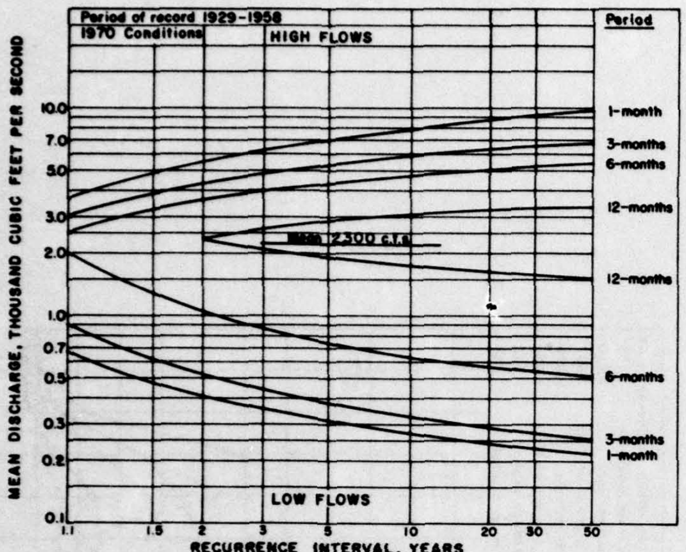


Figure 587 Frequency curves, Sandy River Bl. Bull Run

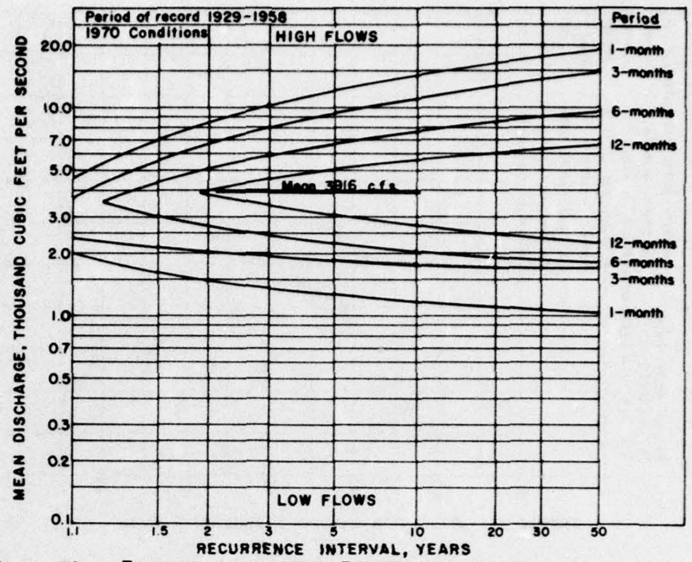


Figure 588 Frequency curves, Middle Fork Willamette at Jasper

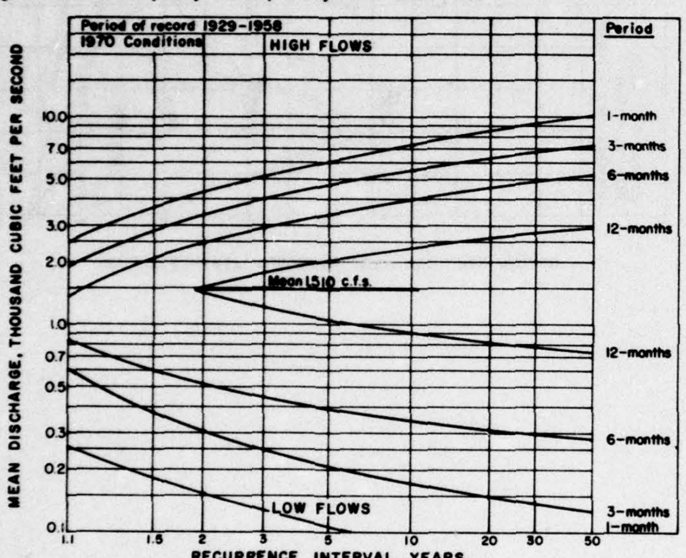


Figure 589 Frequency curves, Coast Fork Willamette River nr Goshen

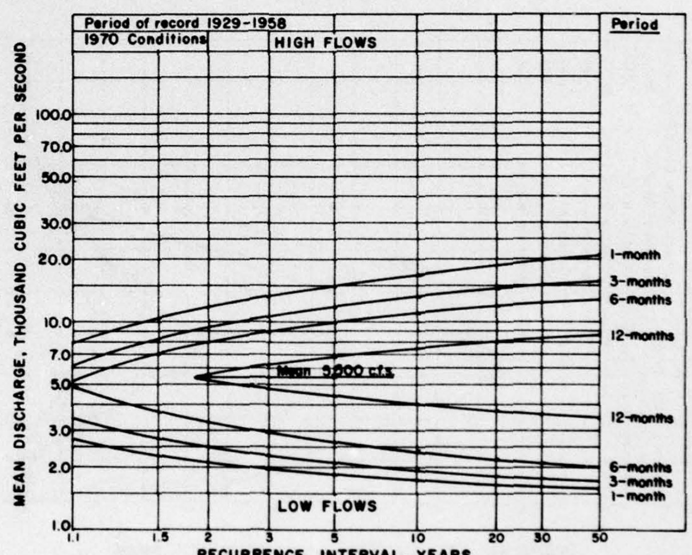


Figure 590 Frequency curves, Mcke..zie River nr. Coburg

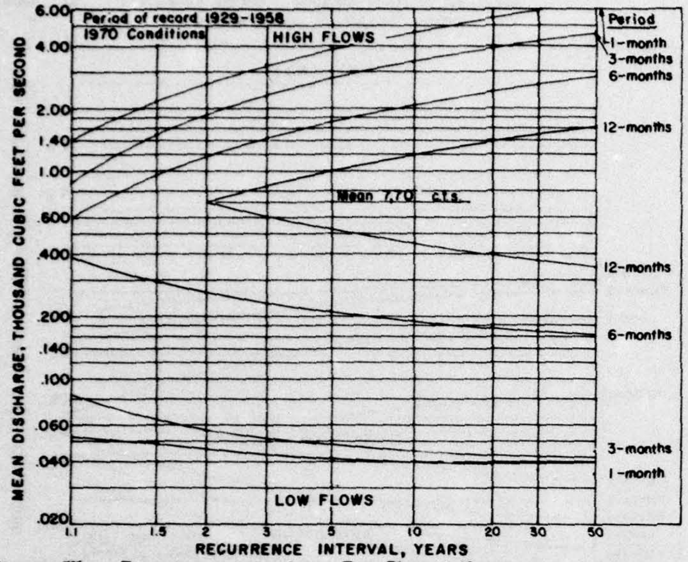


Figure 591 Frequency curves, Long Tom River at Monroe

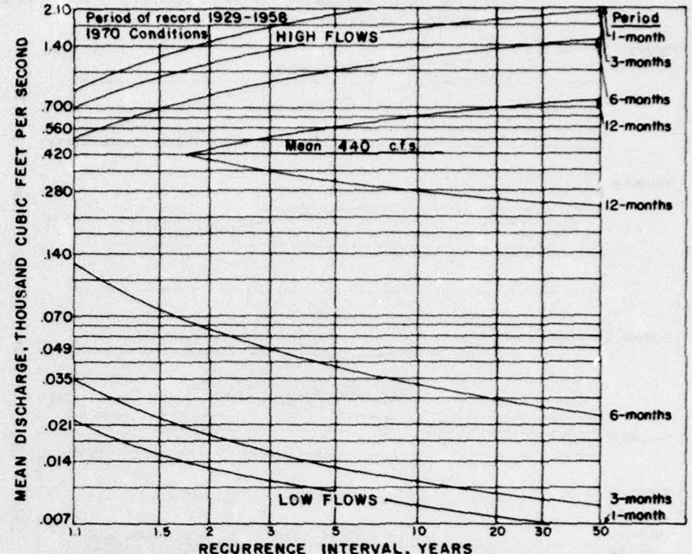


Figure 592 Frequency curves, Marys River nr Philomath

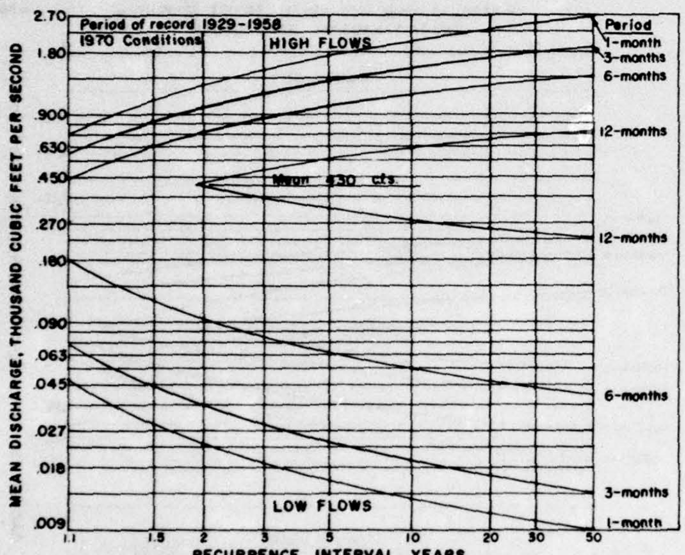


Figure 593 Frequency curves, Calapooia River at Holley

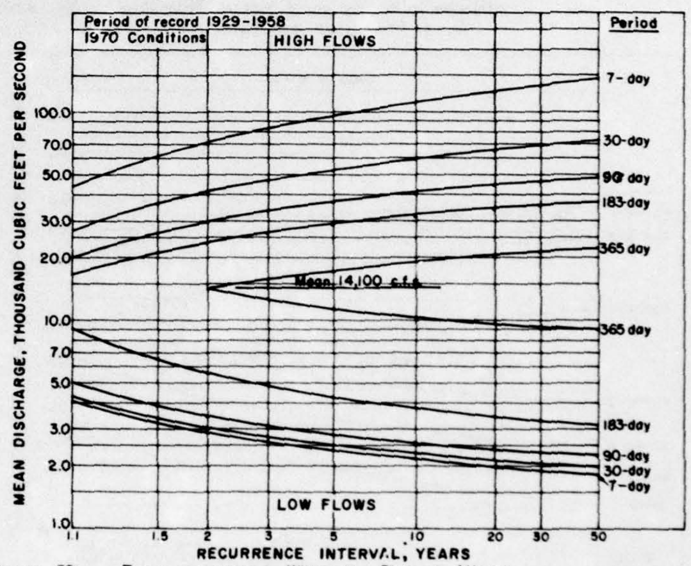


Figure 594 Frequency curves, Willamette River at Albany

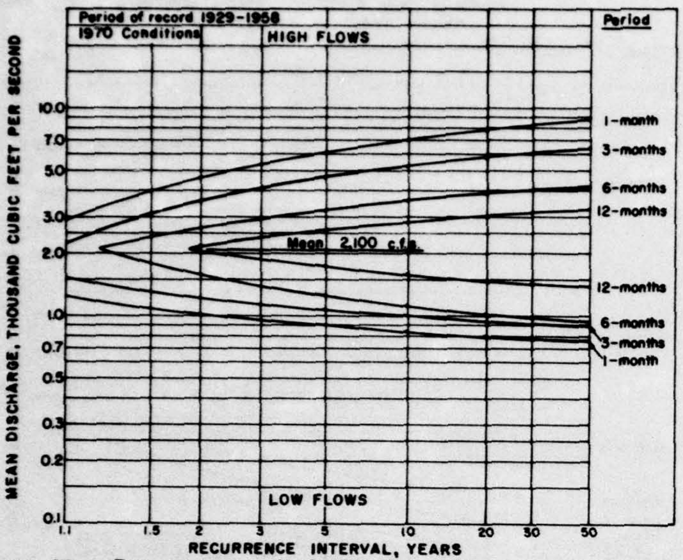


Figure 595 Frequency curves, No. Santiam River at Niagara

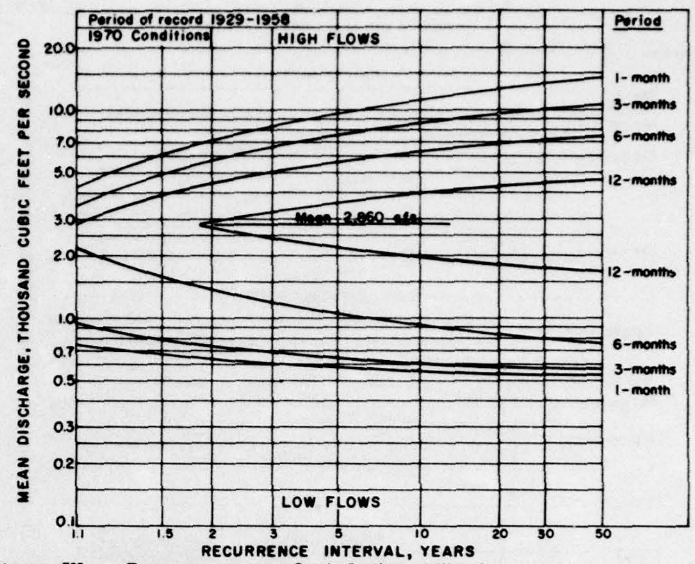


Figure 596 Frequency curves, South Santiam at Waterloo

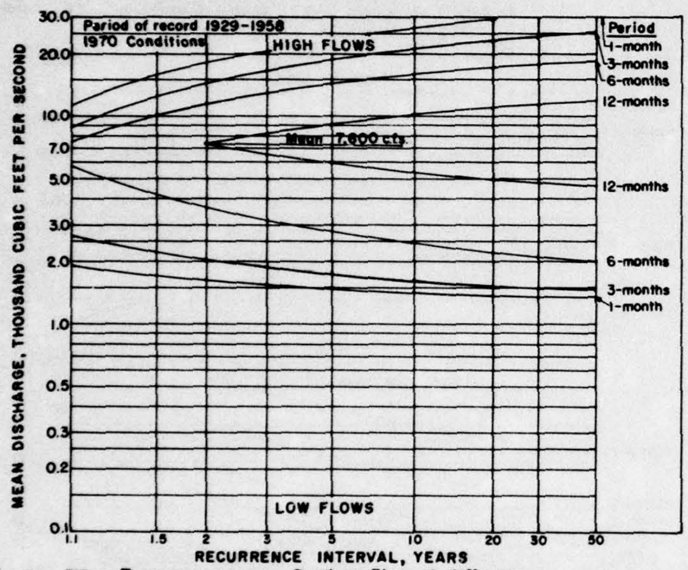


Figure 597 Frequency curves, Santiam River at Jefferson

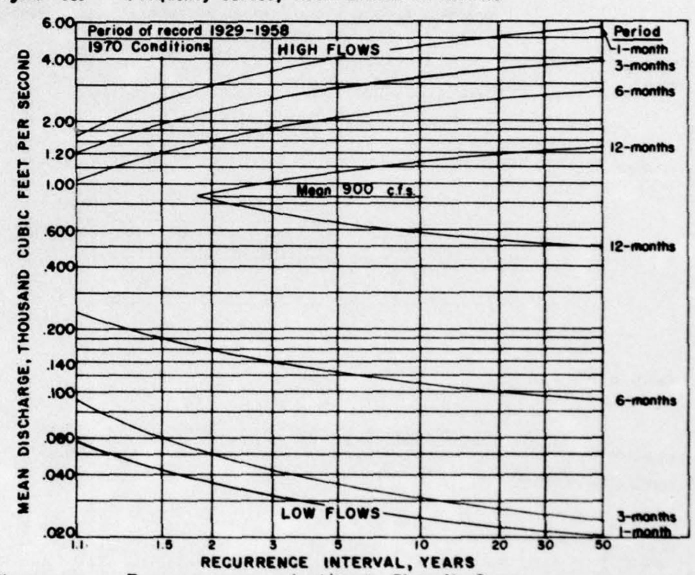


Figure 598 Frequency curves, Luckiamute River Nr. Suver

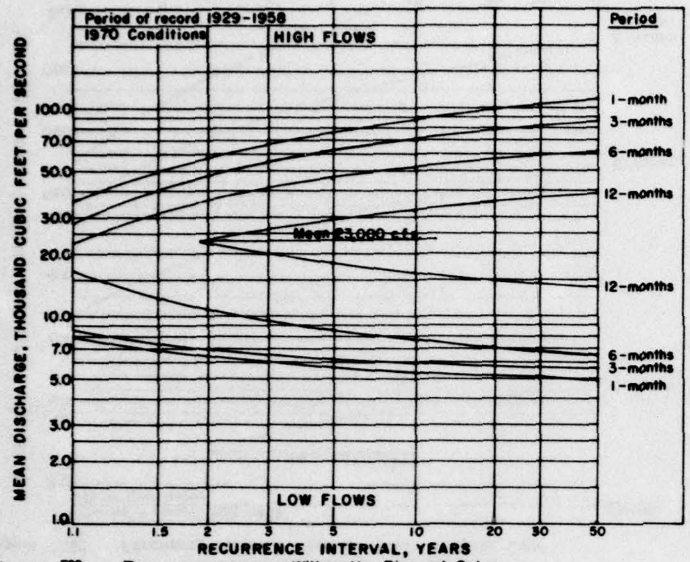


Figure 599 Frequency curves, Willamette River at Salem

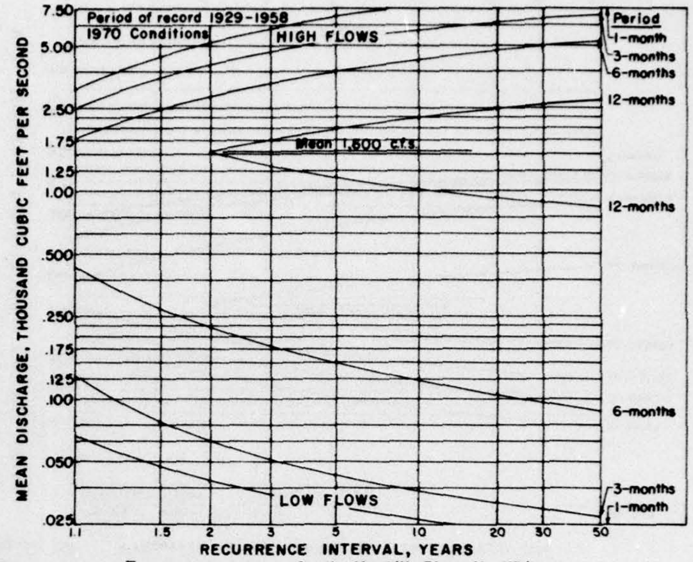


Figure 600 Frequency curves, South Yamhill River Nr. Whiteson

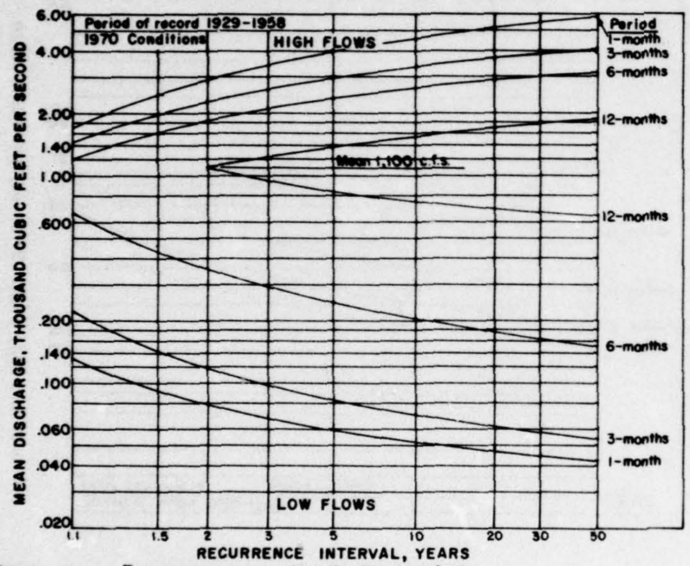


Figure 601 Frequency curves, Molalla River at Canby

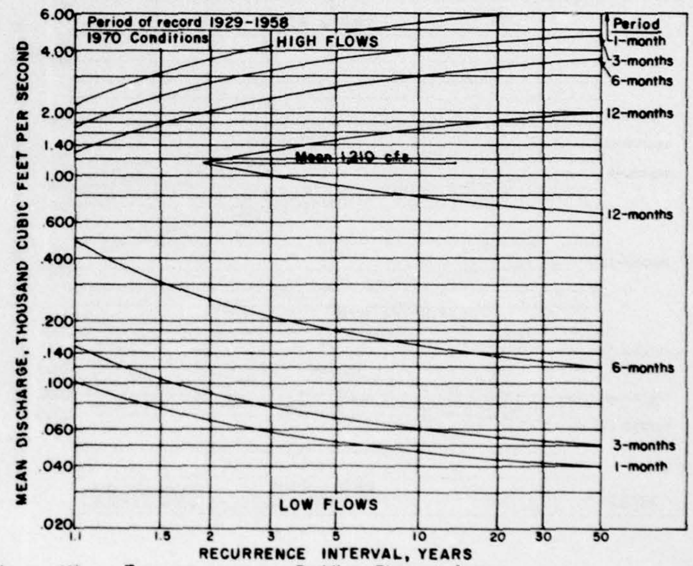


Figure 602 Frequency curves, Pudding River at Aurora

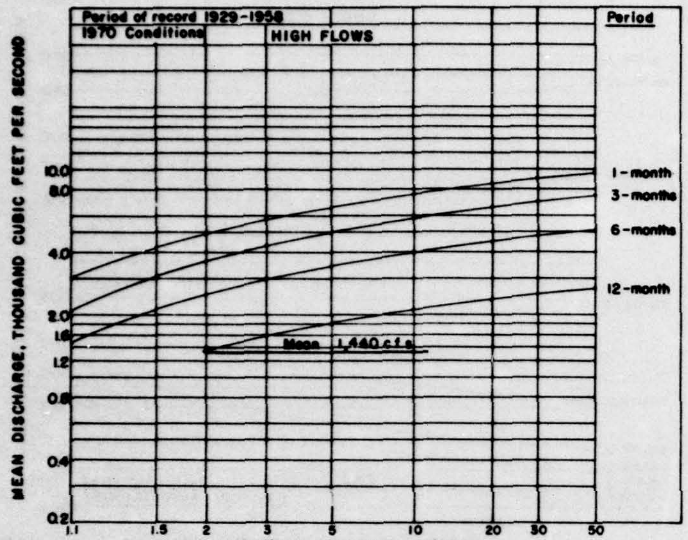


Figure 603 Frequency curves, Tualatin River at West Linn

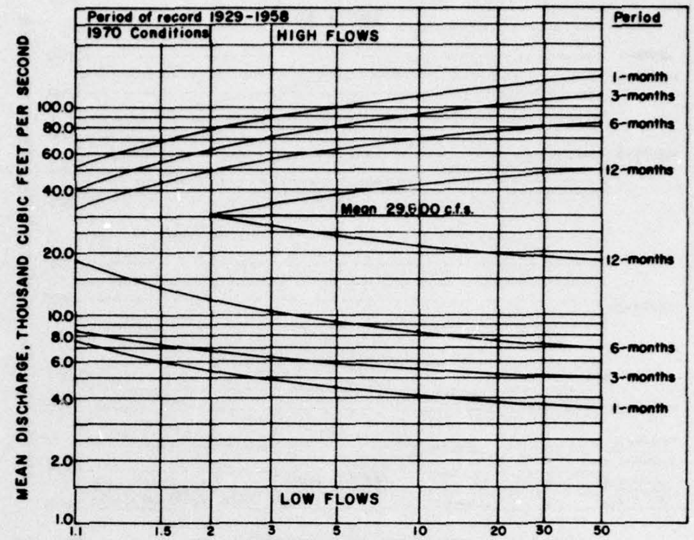


Figure 604 Frequency curves, Willamette River at Oregon City

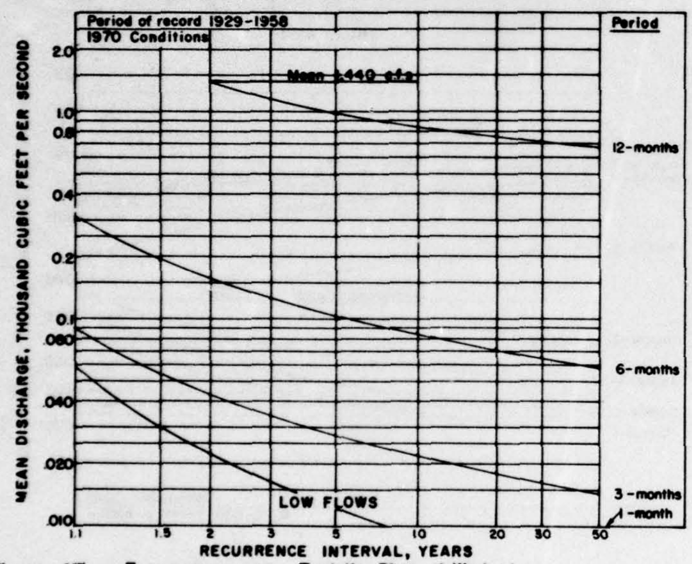


Figure 603 Frequency curves, Tualatin River at West Linn

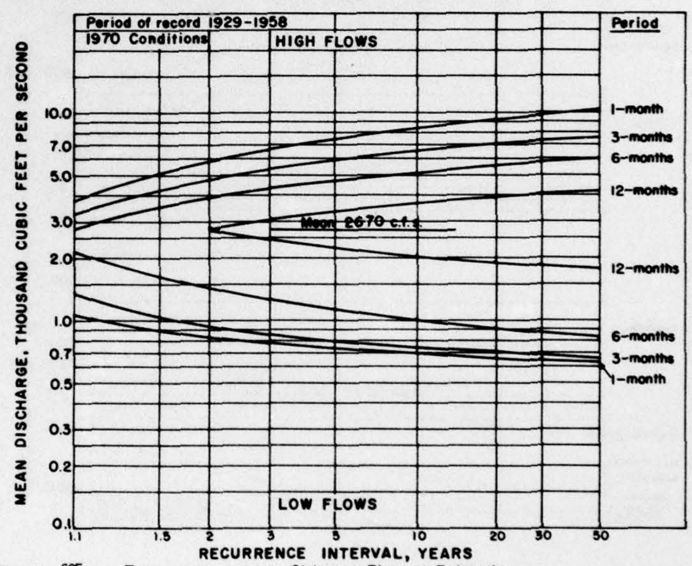


Figure 605 Frequency curves, Clakamas River at Estacadc

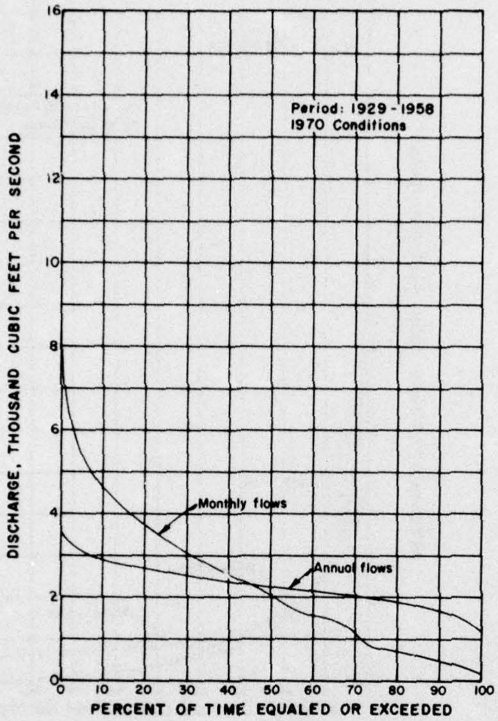


Figure 606 Duration curves, Sandy River near Bull Run, Oregon

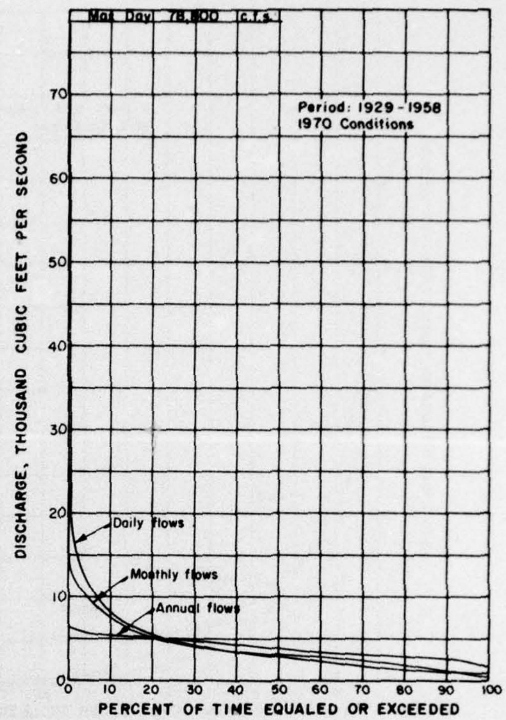


Figure 607 Duration curves, Middle Fork Willamette River at Jasper, Oregon

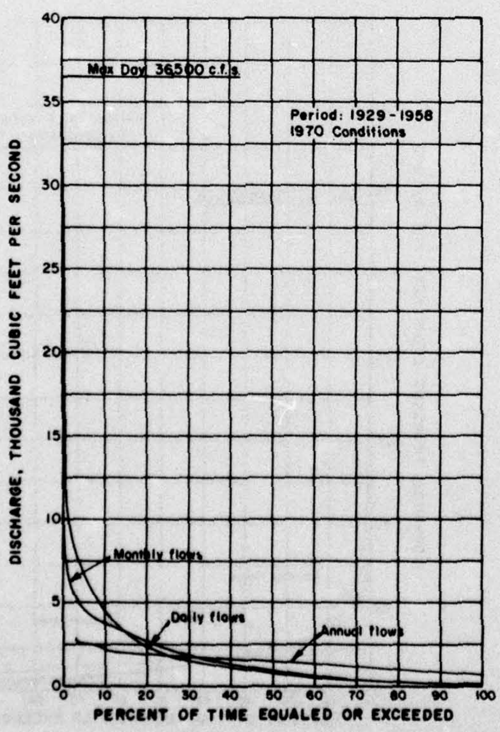


Figure 608 Duration curves, Coast Fork Willamette River near Goshen, Oregon

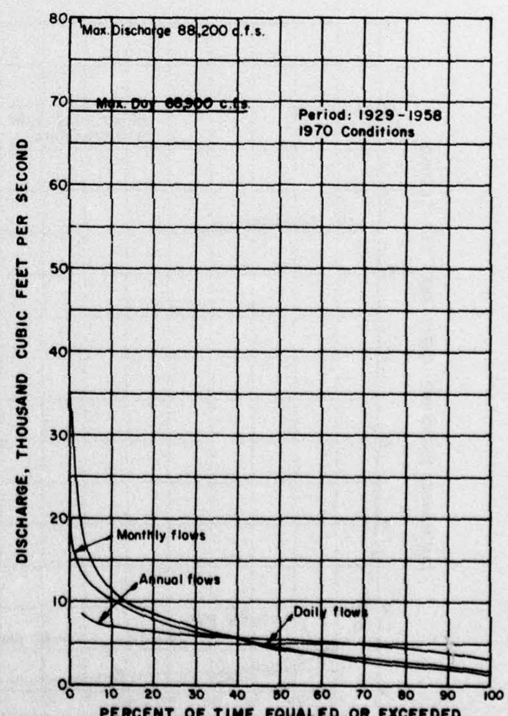


Figure 609 Duration curves, McKenzie River near Coburg, Oregon

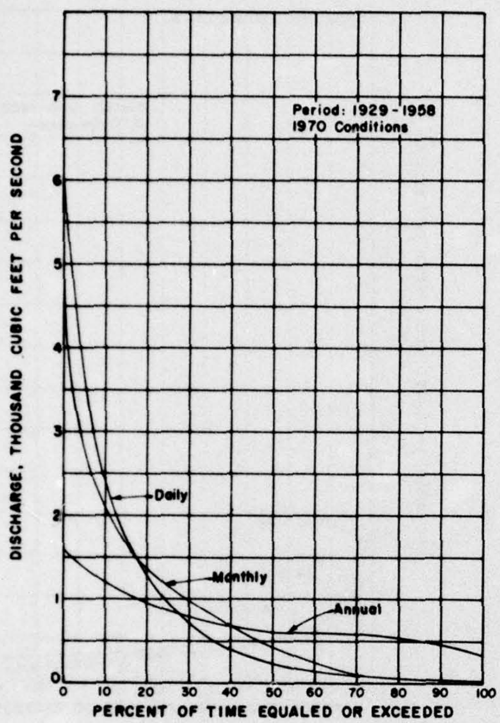


Figure 610 Duration curves, Long Tom River at Monroe, Oregon

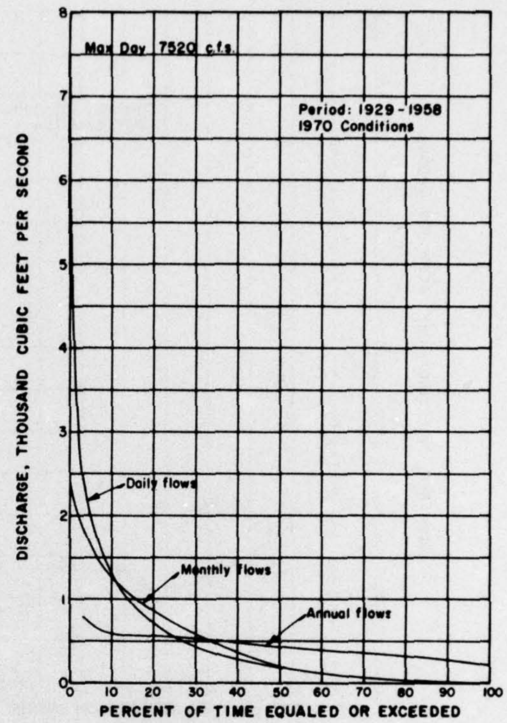


Figure 611 Duration curves, Marys River near Philomath, Oregon

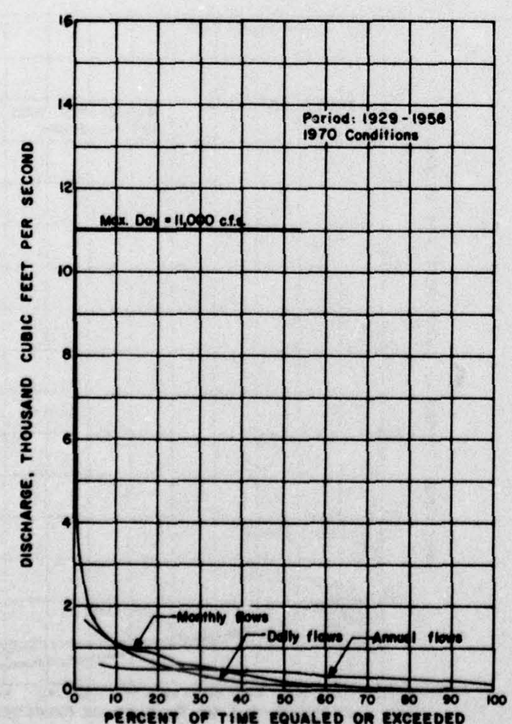


Figure 612 Duration curves, Calapooia River at Holley, Oregon

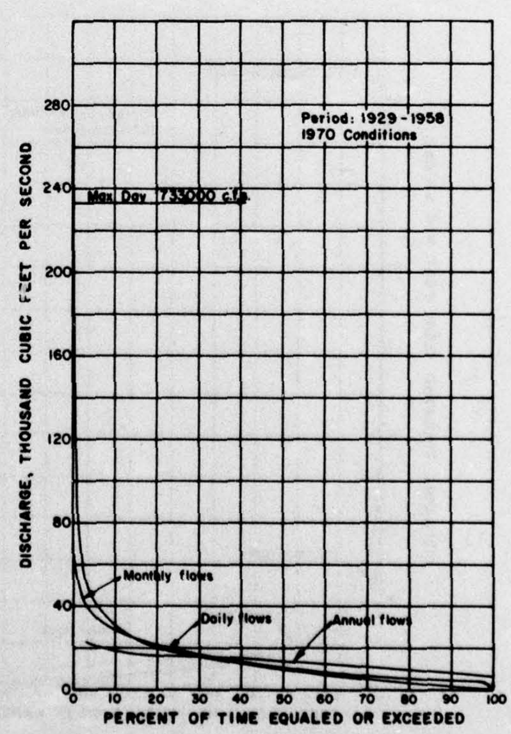


Figure 613 Duration curves, Willamette River at Albany, Oregon

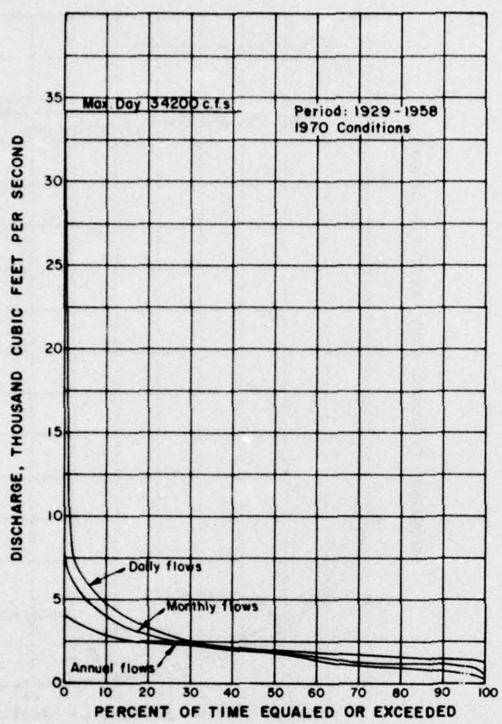


Figure 614 Duration curves, North Santiam River at Niagara, Oregon

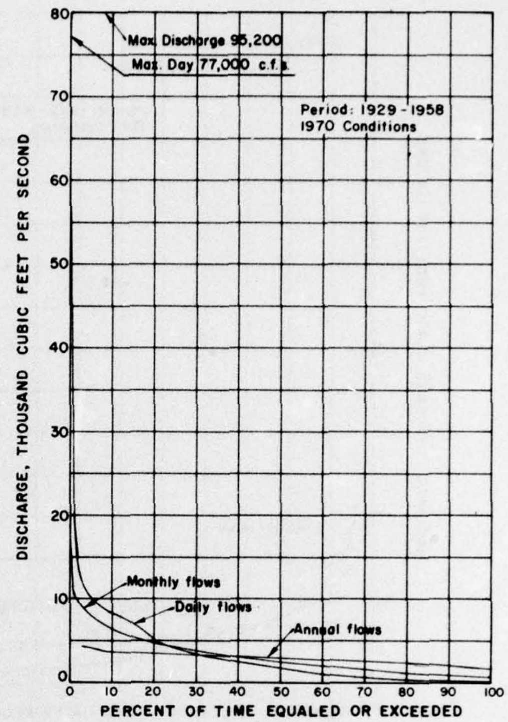


Figure 615 Duration curves, South Santiam River at Waterloo, Oregon

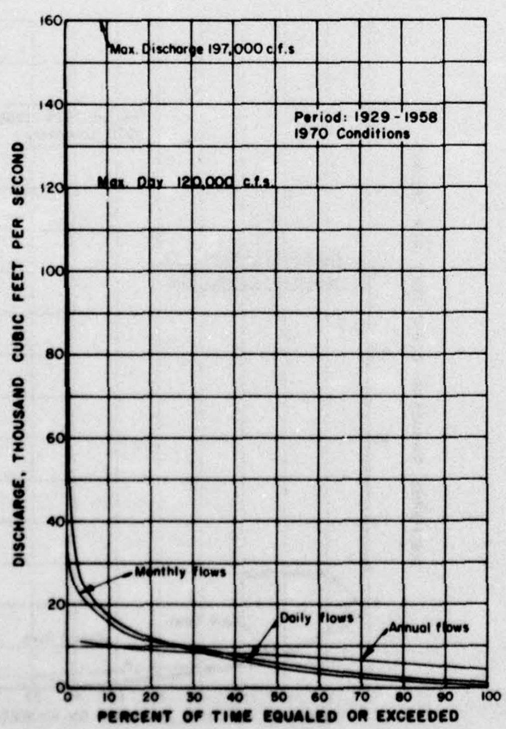


Figure 616 Duration curves, Santiam River at Jefferson, Oregon

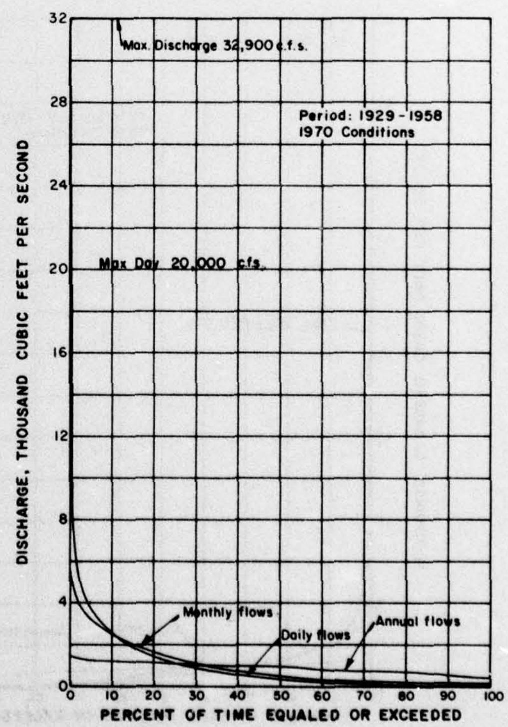


Figure 617 Duration curves, Luckiamute River near Suver, Oregon

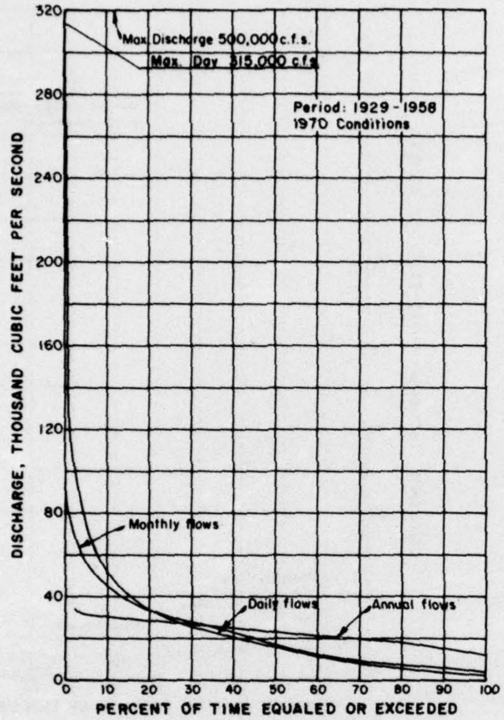


Figure 618 Duration curves, Willamette River at Salem, Oregon

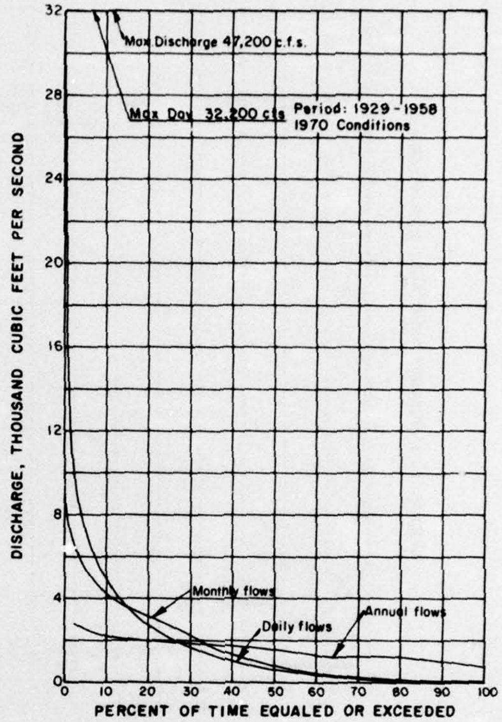


Figure 619 Duration curves, South Yamhill River near Whiteson, Oregon

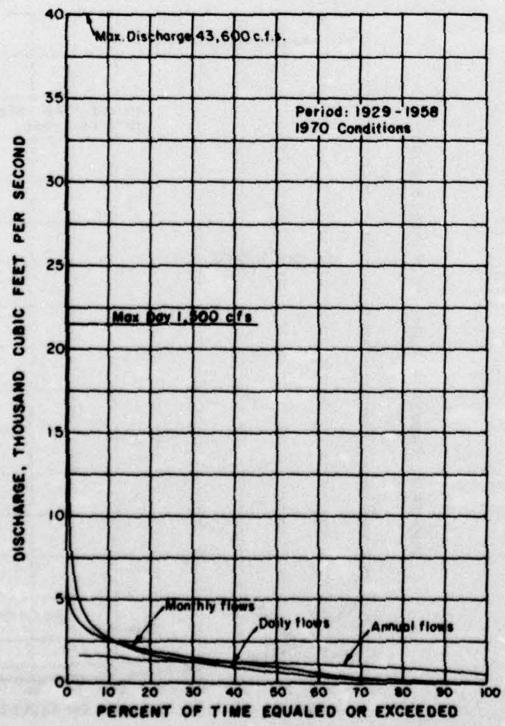


Figure 620 Duration curves, Molalla River near Canby, Oregon

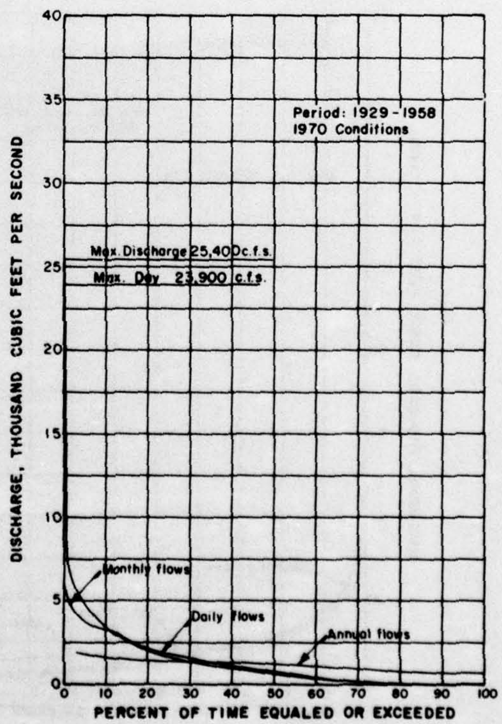


Figure 621 Duration curves, Pudding River at Aurora, Oregon

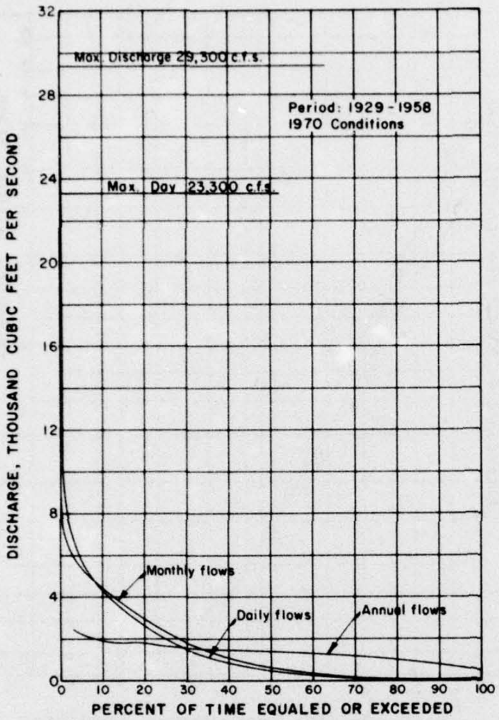


Figure 622 Duration curves, Tualatin River at West Linn, Oregon

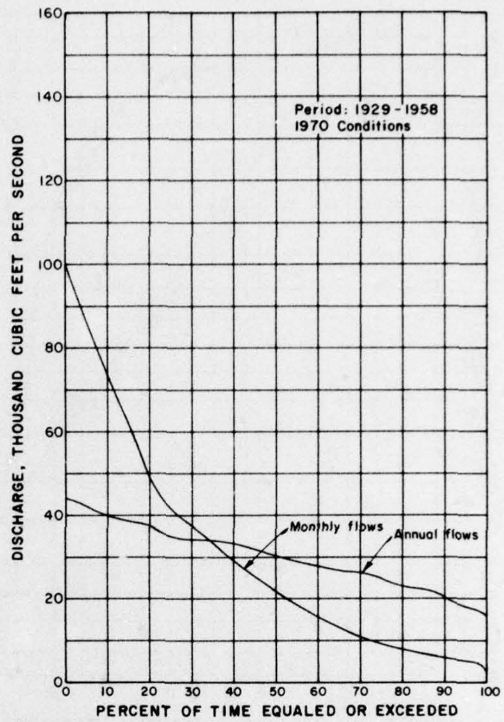


Figure 623 Duration curves, Willamette River at Oregon City, Oregon

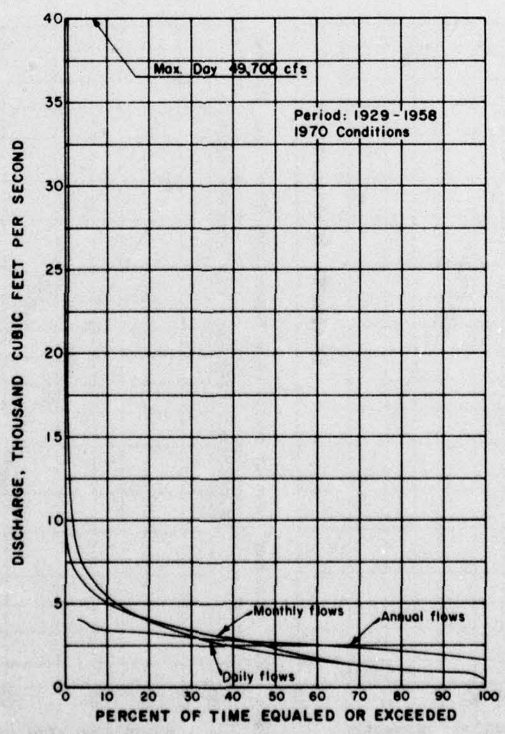


Figure 624 Duration curves, Clackamas River at Estacada, Oregon

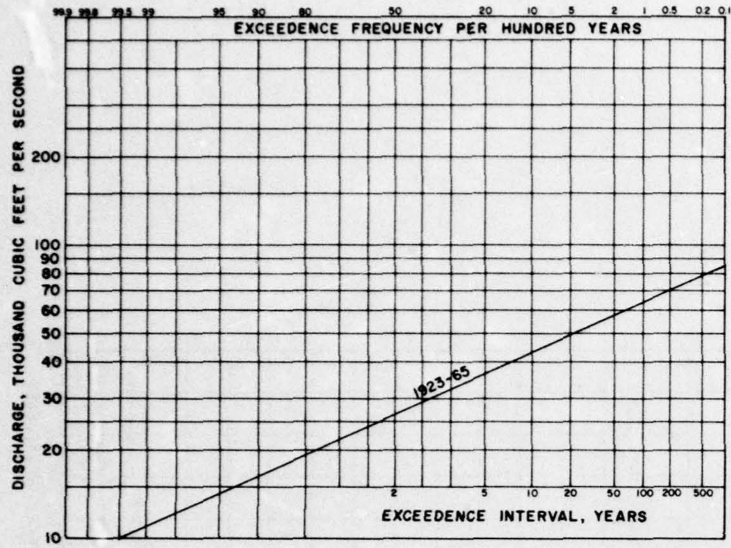


Figure 625 Frequency curve of annual peak flows, Sandy River near Bull Run

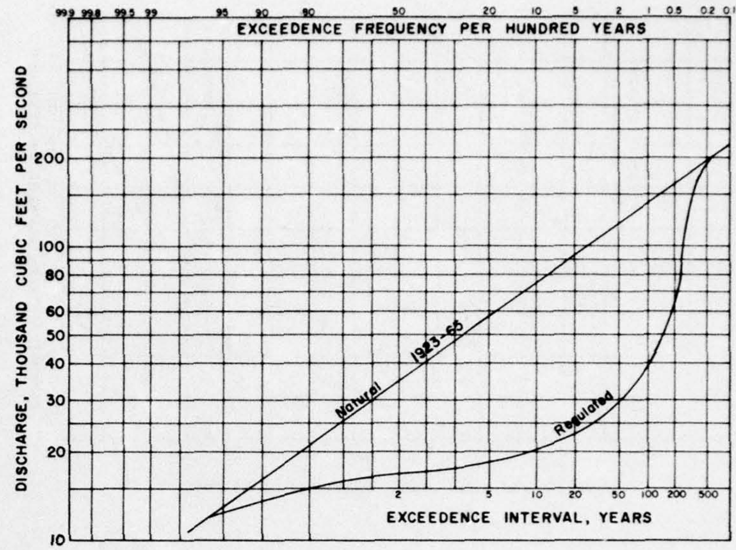


Figure 626 Frequency curve of annual peak flows, Middle Fork Willamette R. at Jasper

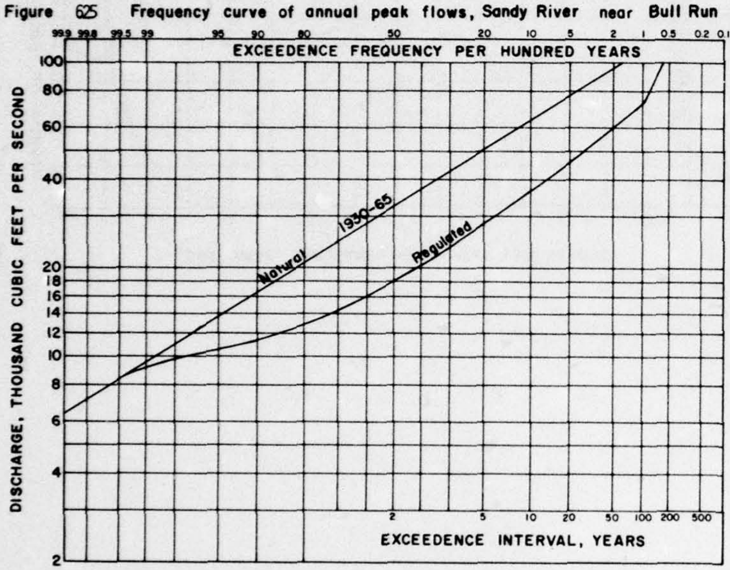


Figure 627 Frequency curve of annual peak flows, Coast Fork Willamette R. nr. Goshen

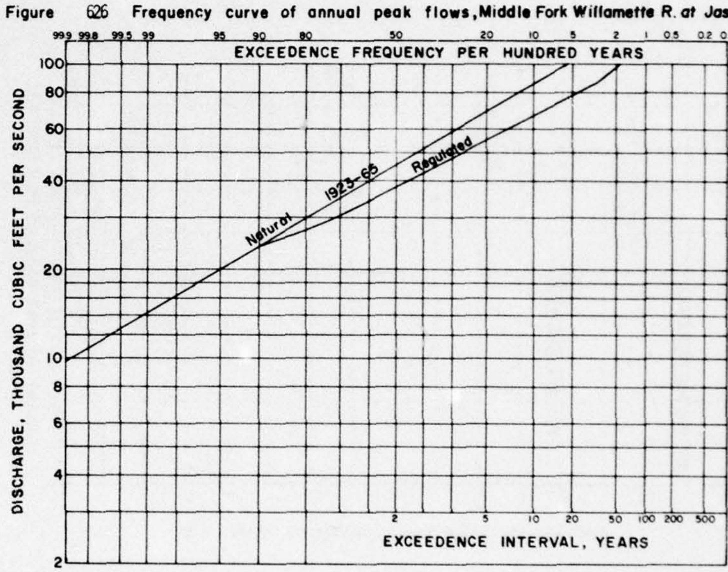


Figure 628 Frequency curve of annual peak flows, McKenzie R. nr. Coburg

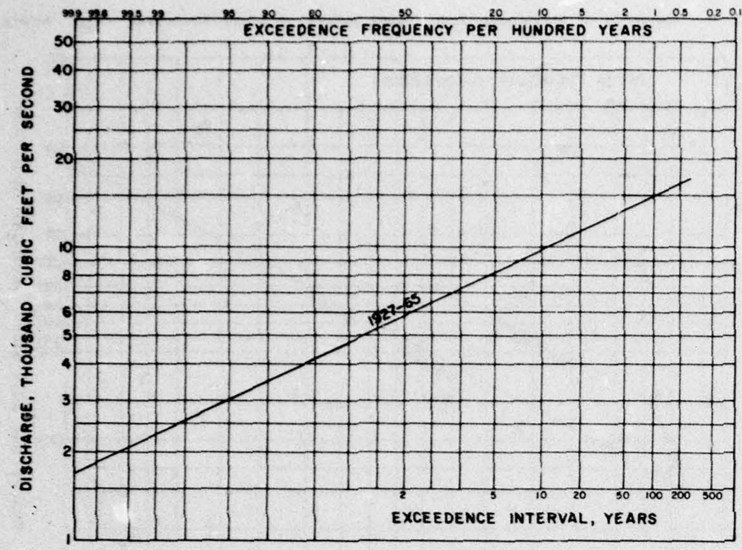


Figure 629 Frequency curve of annual peak flows, Marys R. nr. Philomath

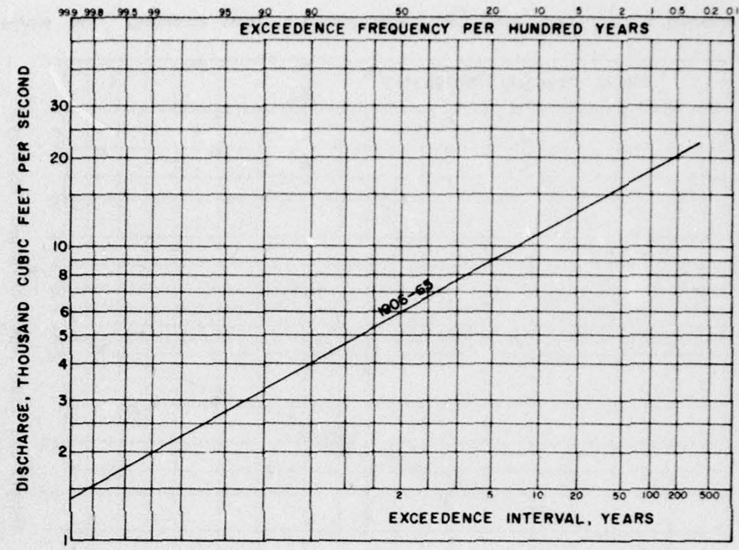


Figure 630 Frequency curve of annual peak flows, Calapooia R. at Holley

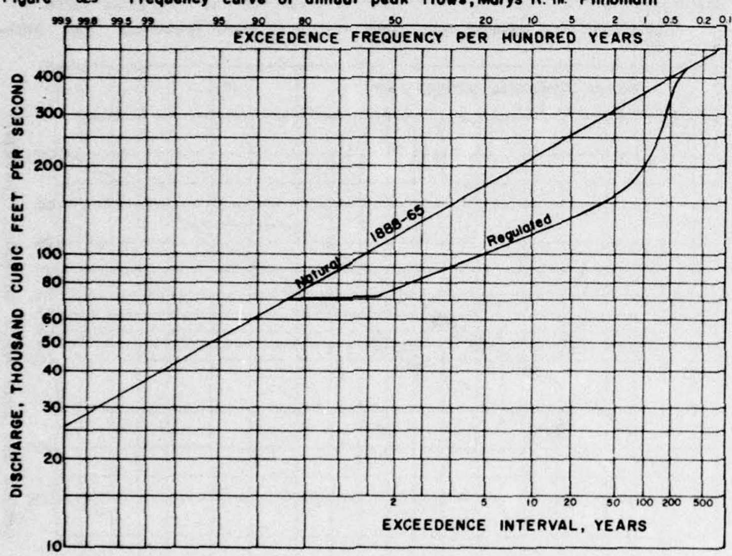


Figure 631 Frequency curve of annual peak flows, Willamette R. at Albany

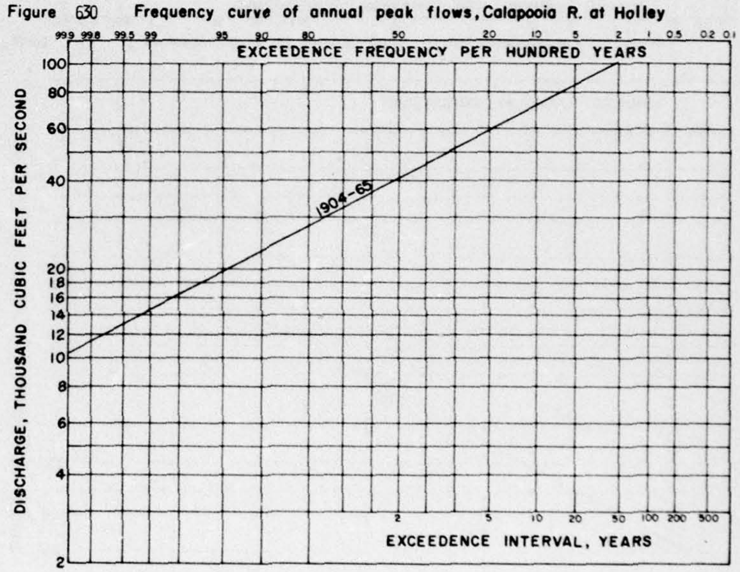
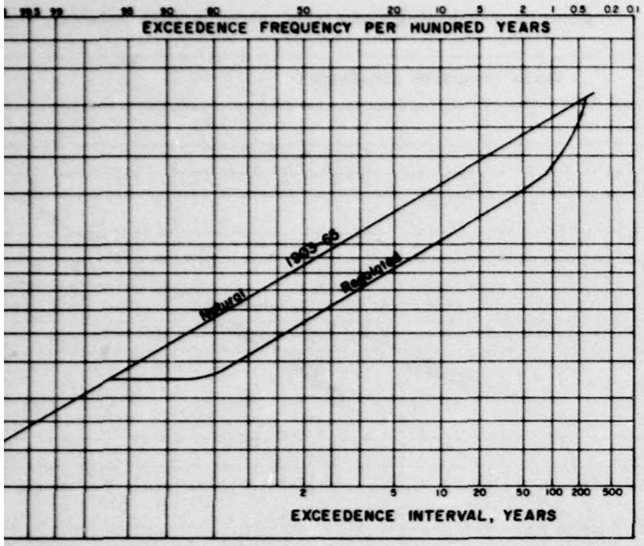
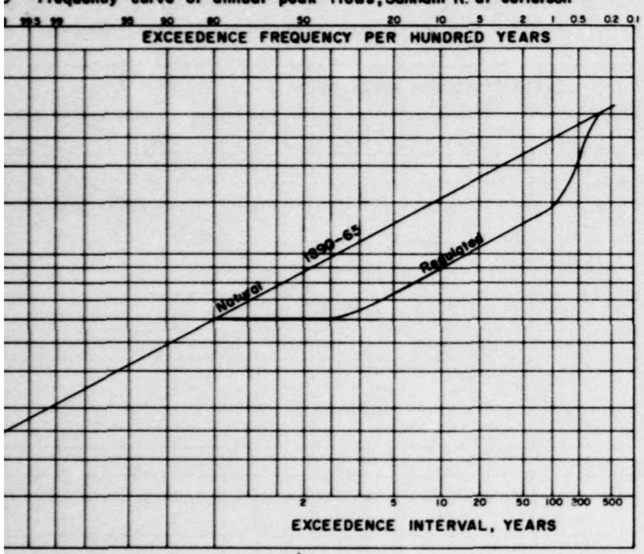


Figure 632 Frequency curve of annual peak flows, South Santiam R. at Waterloo



5 Frequency curve of annual peak flows, Santiam R. at Jefferson



Frequency curve of annual peak flows, Willamette R. at Salem

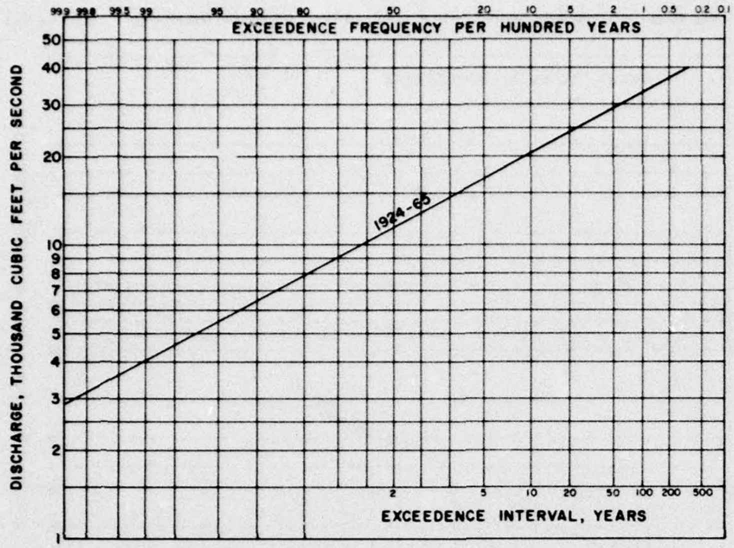


Figure 634 Frequency curve of annual peak flows, Luckiamute R. nr. Suver

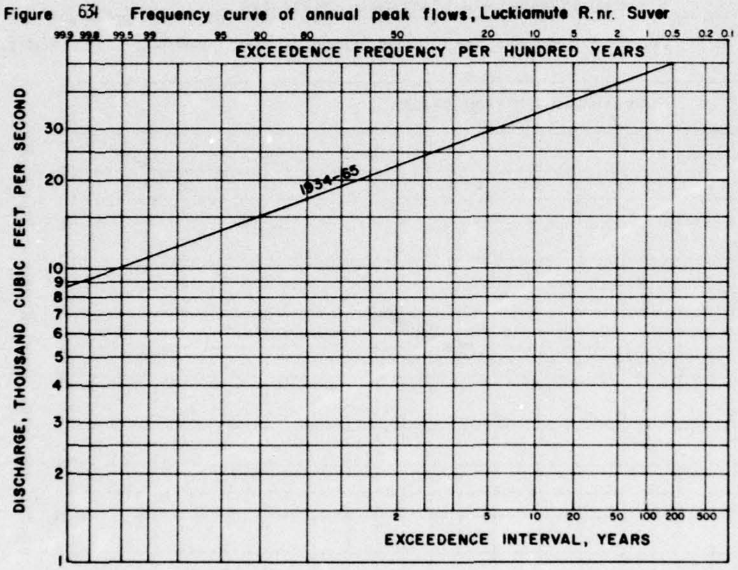


Figure 636 Frequency curve of annual peak flows, South Yamhill River nr. Whiteson

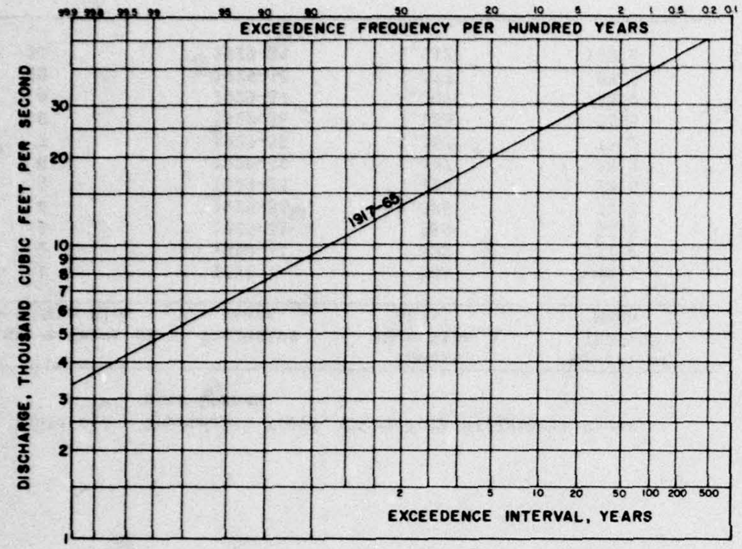


Figure 637 Frequency curve of annual peak flows, Molalla River nr Canby

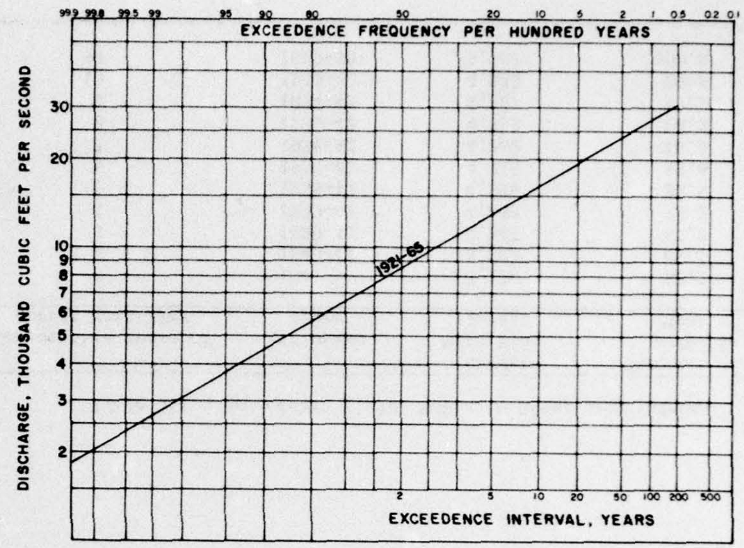


Figure 638 Frequency curve of annual peak flows, Pudding River at Aurora

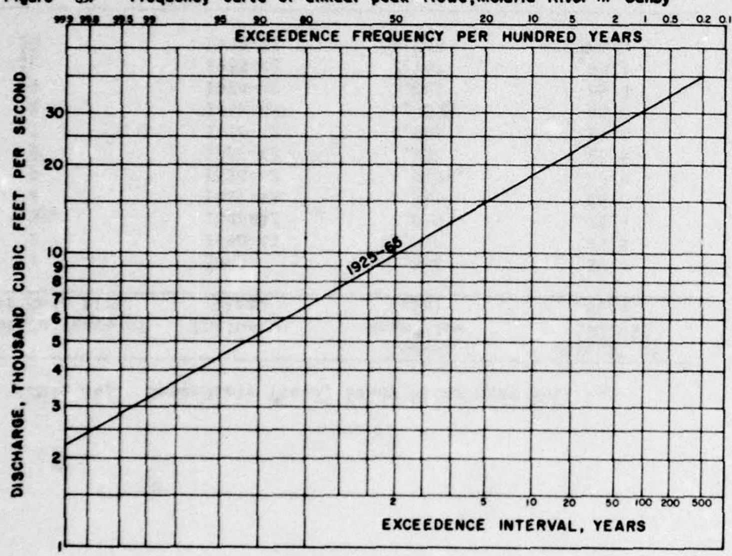


Figure 639 Frequency curve of annual peak flows, Tualatin River at West Linn

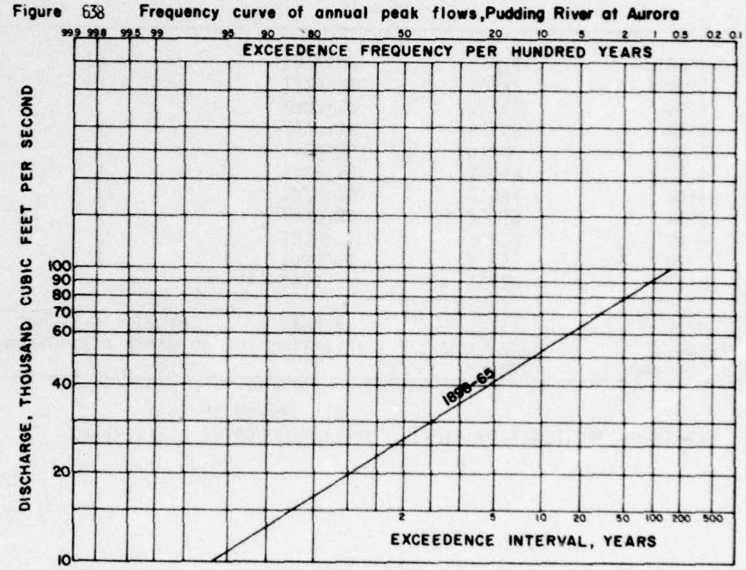


Figure 640 Frequency curve of annual peak flows, Clackamas River at Estacada

Table 341. Dependable Yield, Sandy River near Bull Run

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	1,368	59.3
2	1940-41	1,540	66.8
3	1940-42	1,679	72.8
4	1939-42	1,751	76.0
5	1938-42	1,914	83.0
6	1937-42	1,932	83.8
7	1936-42	1,951	84.6
8	1935-42	1,995	86.6
9	1934-42	2,061	89.4
10	1933-42	2,147	93.1
30	1929-58	2,302	100.0

Table 342. Dependable Yield, Middle Fork Willamette River at Jasper

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	2,130	54.8
2	1930-31	3,453	63.1
3	1929-31	2,513	64.6
4	1929-32	2,759	70.9
5	1929-33	3,094	79.6
6	1929-34	3,068	78.9
7	1929-35	3,120	80.2
8	1929-36	3,153	81.1
9	1929-37	3,168	81.5
10	1929-38	3,347	86.1
30	1929-58	3,916	100.0

Table 343. Dependable Yield, Coast Fork Willamette River near Goshen

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	705	46.6
2	1930-31	829	54.8
3	1929-31	889	58.8
4	1929-32	1,076	71.2
5	1929-33	1,187	78.5
6	1929-34	1,107	73.2
7	1929-35	1,167	77.2
8	1929-36	1,186	78.5
9	1929-37	1,207	79.9
10	1929-38	1,277	84.5
30	1929-58	1,512	100.0

Table 344. Dependable Yield, McKenzie River near Coburg

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	3,170	57.5
2	1940-41	3,585	65.1
3	1939-41	3,847	69.9
4	1939-42	4,033	73.2
5	1938-42	4,598	83.5
6	1937-42	4,715	85.6
7	1936-42	4,768	86.5
8	1935-42	4,859	88.2
9	1934-42	4,807	87.3
10	1933-42	4,942	89.8
30	1929-58	5,508	100.0

Table 345. Dependable Yield, Long Tom River at Monroe

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	328	42.3
2	1930-31	411	53.0
3	1929-31	415	53.5
4	1929-32	507	65.4
5	1929-33	565	72.9
6	1929-34	547	70.6
7	1929-35	582	75.1
8	1929-36	591	76.2
9	1929-37	604	77.9
10	1929-38	662	85.4
30	1929-58	770	100.0

Table 346. Dependable Yield, Mary's River near Philomath

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	237	53.8
2	1930-31	278	63.1
3	1929-31	285	64.7
4	1939-42	321	72.9
5	1938-42	368	83.5
6	1937-42	373	84.7
7	1936-42	371	84.2
8	1935-42	379	86.0
9	1934-42	384	87.2
10	1933-42	381	86.5
30	1929-58	444	100.0

Table 347. Dependable Yield, Calapooia River at Holley

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	221	51.3
2	1930-31	241	55.9
3	1929-31	256	59.4
4	1929-32	316	73.3
5	1929-33	349	81.0
6	1929-34	382	88.6
7	1929-35	349	81.0
8	1929-36	352	81.7
9	1929-37	358	83.1
10	1929-38	376	87.2
30	1929-58	438	100.0

Table 348. Dependable Yield, Willamette River at Albany

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	7,646	54.5
2	1930-31	8,508	60.7
3	1939-41	9,110	65.0
4	1939-42	9,917	70.8
5	1939-43	11,857	84.5
6	1939-44	11,318	80.8
7	1939-45	11,355	81.0
8	1939-46	11,906	85.0
9	1939-47	12,135	86.6
10	1939-48	12,748	91.0
30	1929-58	14,111	100.0

Table 349. Dependable Yield, North Santiam River at Niagara

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1,424	66.9
2	1930-31	1,475	69.3
3	1939-41	1,545	72.6
4	1939-42	1,546	72.7
5	1938-42	1,698	79.8
6	1937-42	1,716	80.7
7	1936-42	1,735	81.5
8	1935-42	1,741	81.8
9	1934-42	1,774	83.4
10	1933-42	1,829	86.0
30	1929-58	2,102	100.0

Table 350. Dependable Yield, South Santiam River at Waterloo

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	1,741	60.7
2	1930-31	1,867	65.0
3	1929-31	1,986	69.4
4	1939-42	2,066	71.9
5	1938-42	2,342	81.5
6	1937-42	2,380	82.9
7	1936-42	2,397	83.5
8	1935-42	2,417	84.2
9	1934-42	2,422	84.4
10	1933-42	2,533	88.1
30	1929-58	2,856	100.0

Table 351. Dependable Yield, Santiam River at Jefferson

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	4,656	61.3
2	1930-31	5,036	66.1
3	1929-31	5,345	70.2
4	1939-42	5,651	74.4
5	1938-42	6,319	84.0
6	1939-44	6,283	82.7
7	1939-45	6,280	82.5
8	1939-46	6,510	85.6
9	1937-45	6,625	87.1
10	1936-45	6,638	86.0
30	1929-58	7,596	100.0

Table 352. Dependable Yield, Luckiamute River near Suver

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1		462	51.2
2	1941-42	578	63.6
3	1940-42	645	71.0
4	1939-42	643	70.7
5	1941-45	712	78.3
6	1940-45	723	79.5
7	1939-45	711	78.8
8	1939-46	747	82.2
9	1939-47	764	84.0
10	1936-45	771	84.8
30	1929-58	903	100.0

Table 353. Dependable Yield, Willamette River at Salem

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	13,529	58.7
2	1930-31	14,516	63.0
3	1929-31	15,115	65.7
4	1939-42	16,663	72.3
5	1929-33	18,770	81.5
6	1929-34	18,721	81.2
7	1939-45	18,902	82.0
8	1938-45	20,188	87.6
9	1929-37	19,370	84.1
10	1935-44	20,488	88.9
30	1929-58	22,991	100.0

Table 354. Dependable Yield, South Yamhill River near Whiteson

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	844	52.6
2	1941-42	1,026	64.0
3	1929-31	1,042	65.0
4	1929-32	1,221	76.3
5	1941-45	1,246	77.8
6	1941-46	1,374	85.8
7	1939-45	1,243	77.6
8	1935-42	1,328	82.8
9	1936-44	1,341	83.7
10	1936-45	1,337	83.5
30	1929-58	1,611	100.0

Table 355. Dependable Yield, Molalla River near Canby

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	669	58.9
2	1930-31	720	63.4
3	1929-31	744	65.5
4	1929-32	861	75.8
5	1929-33	938	82.5
6	1940-45	951	83.7
7	1939-45	929	81.8
8	1935-42	950	83.6
9	1929-37	959	84.4
10	1929-38	1,005	88.4
30	1929-58	1,135	100.0

Table 356. Dependable Yield, Pudding River at Aurora

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	695	57.5
2	1929-30	790	65.4
3	1929-31	788	65.2
4	1939-42	875	72.4
5	1945-48	803	66.4
6	1940-45	1,016	84.0
7	1939-45	986	81.5
8	1939-46	1,028	85.0
9	1939-47	1,038	85.7
10	1936-48	1,022	84.5
30	1929-58	1,215	100.0

Table 357. Dependable Yield, Tualatin River at West Linn

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	671	46.3
2	1930-31	716	49.4
3	1930-32	748	51.6
4	1930-33	961	66.3
5	1930-34	1,119	77.2
6	1939-44	1,108	76.5
7	1939-45	1,095	75.6
8	1939-46	1,172	81.9
9	1939-47	1,186	83.0
10	1937-46	1,260	88.0
30	1929-58	1,443	100.0

Table 358. Dependable Yield, Willamette River at Oregon City

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	7,660	59.2
2	1930-31	19,054	63.8
3	1929-31	19,710	66.0
4	1929-32	22,602	75.7
5	1940-44	24,406	81.8
6	1939-44	24,430	81.8
7	1939-45	24,537	82.2
8	1929-36	25,722	86.2
9	1929-37	25,872	86.7
10	1936-45	26,273	88.0
30	1929-58	29,899	100.0

Table 359. Dependable Yield, Clackamas River at Estacada

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	1,712	63.3
2	1940-41	1,906	70.5
3	1929-31	1,943	71.9
4	1929-32	2,095	77.5
5	1938-42	2,249	83.2
6	1939-44	2,243	83.0
7	1939-45	2,244	83.0
8	1936-42	2,327	86.1
9	1935-42	2,364	87.5
10	1936-45	2,366	87.5
30	1929-58	2,674	100.0

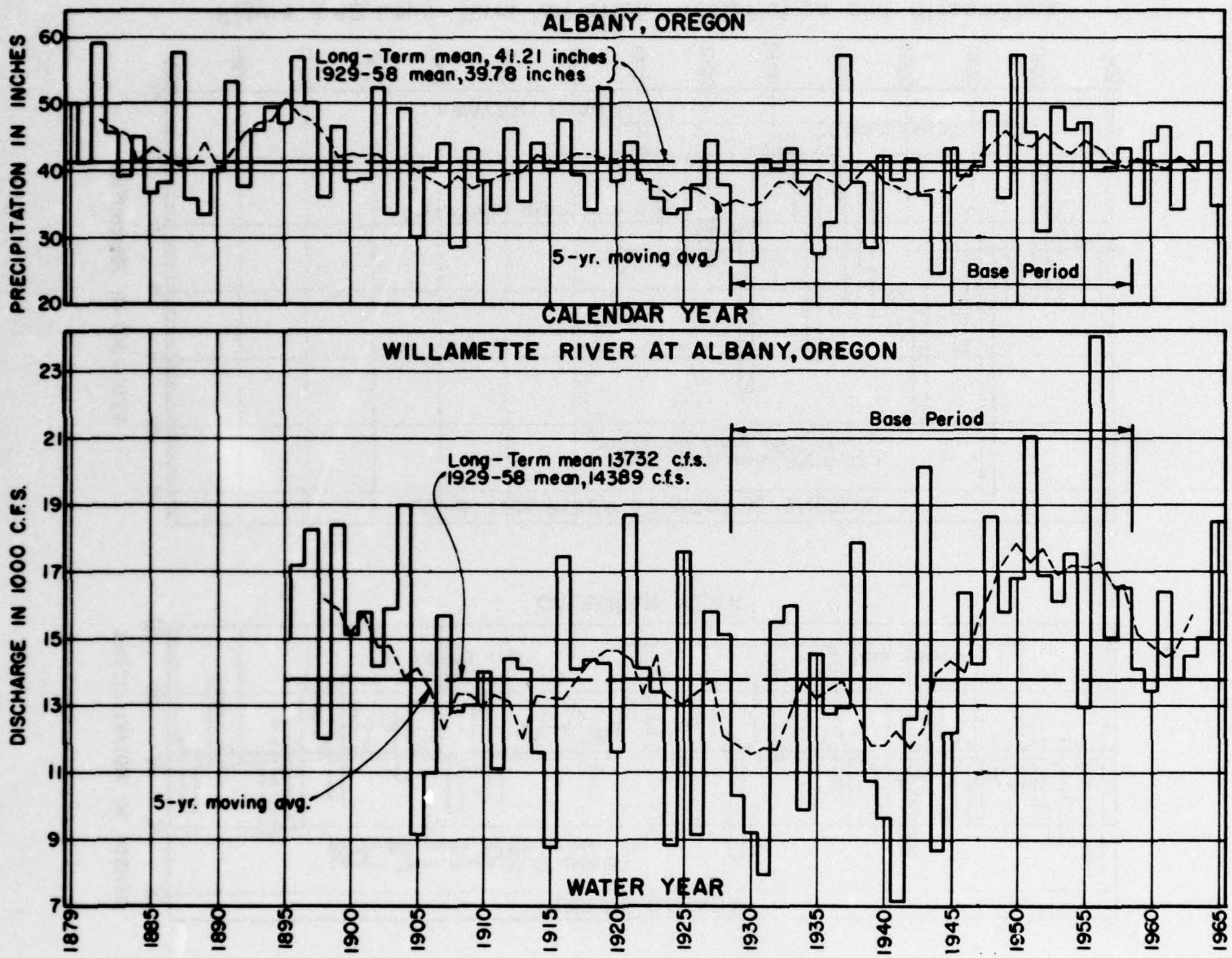


Figure 641. Long-Term Variation in Precipitation and Streamflow.

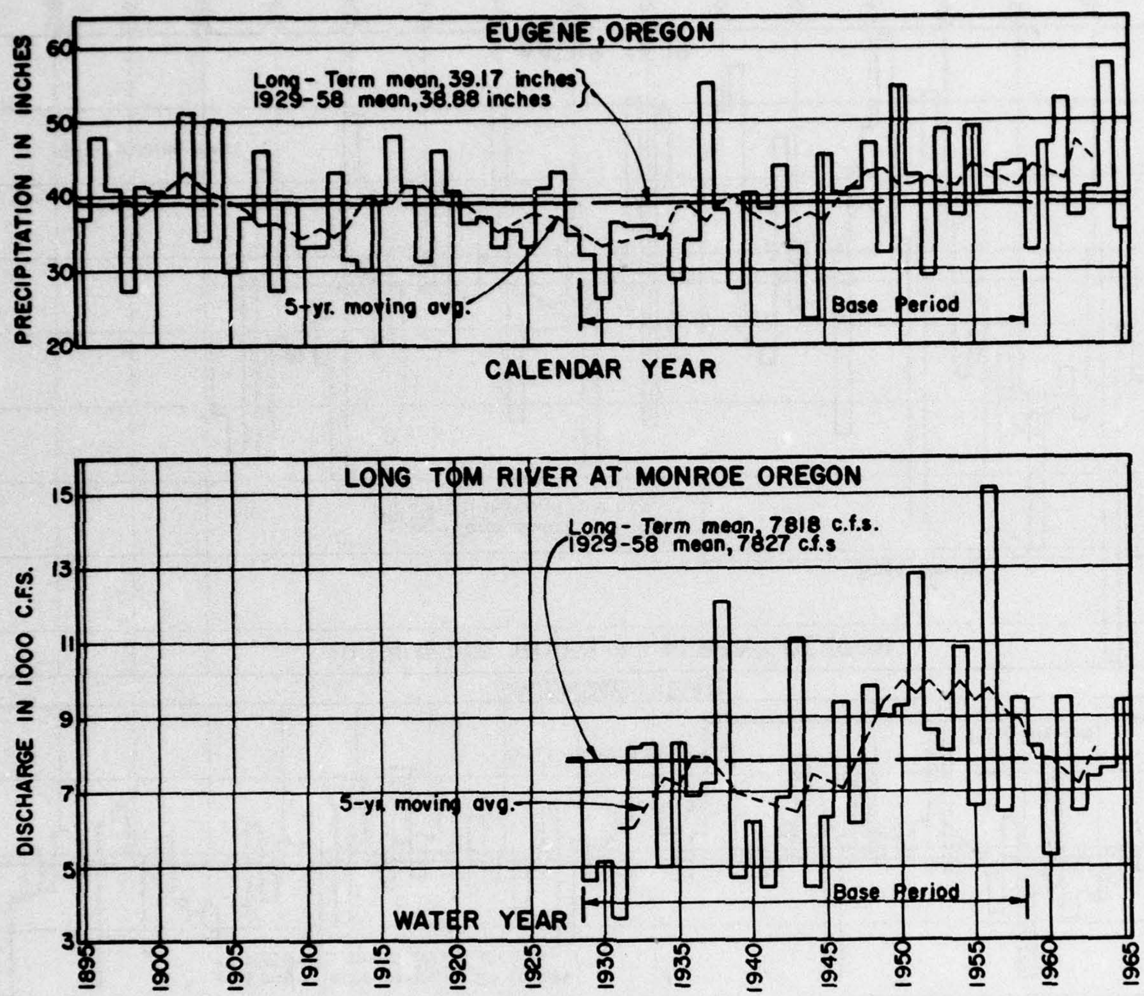


Figure 642. Long-Term Variation Precipitation and Streamflow.

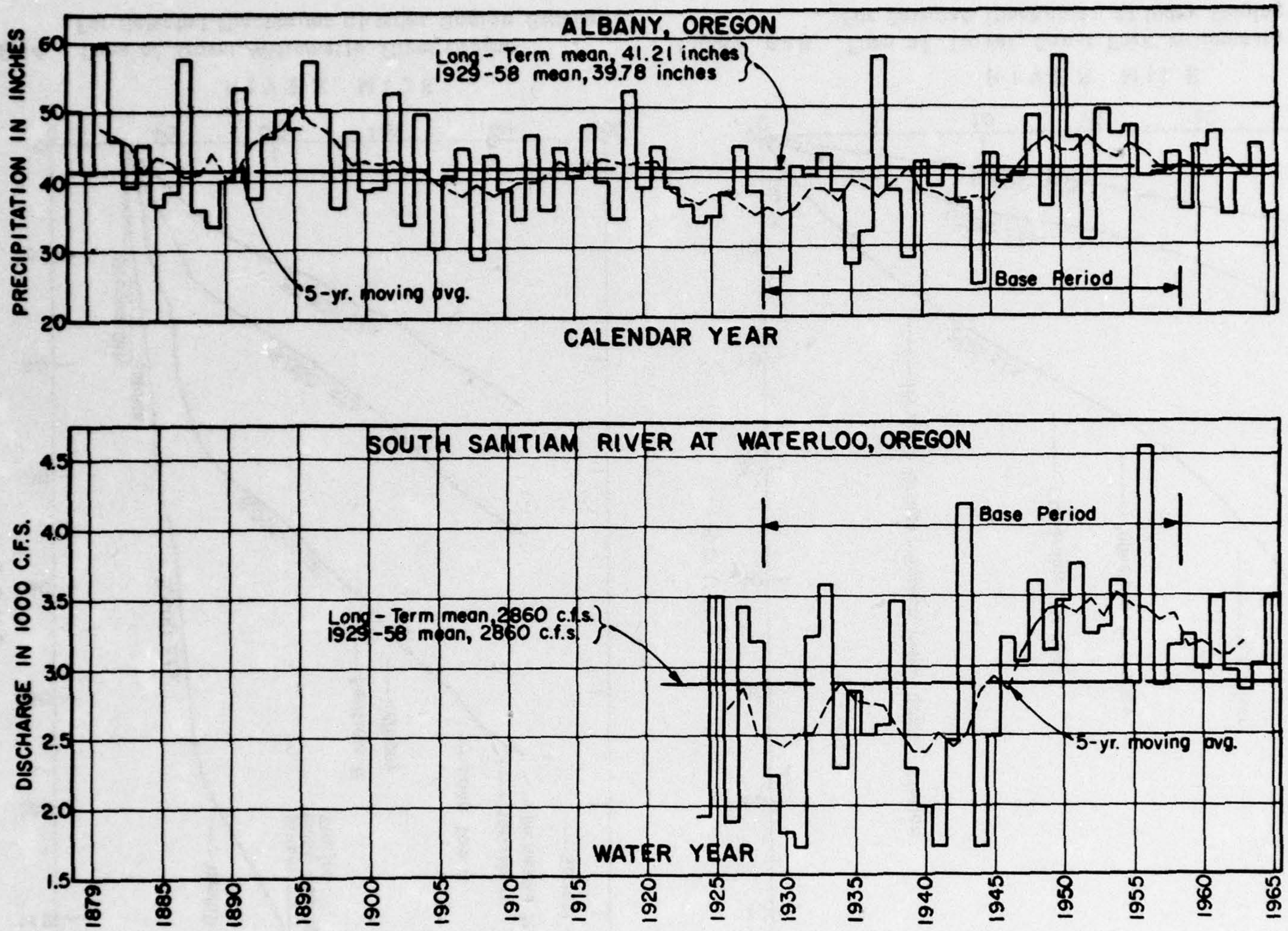


Figure 643. Long-Term Variation Precipitation and Streamflow.

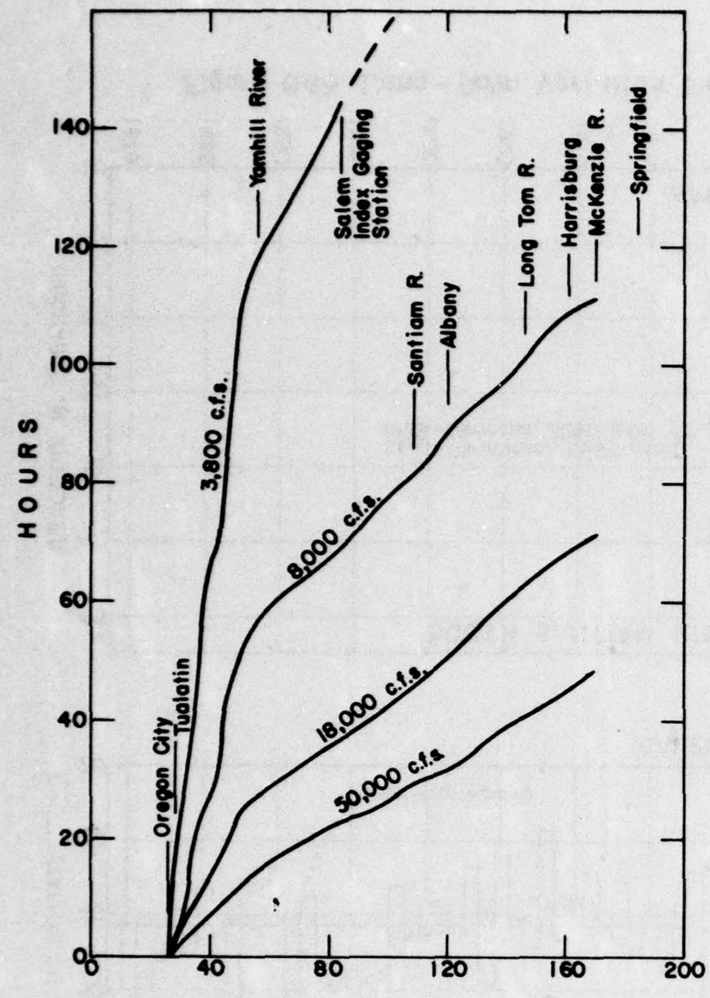


Figure 644. Time of Travel, Willamette River, Oregon
For Selected Discharges at Index Gaging Station

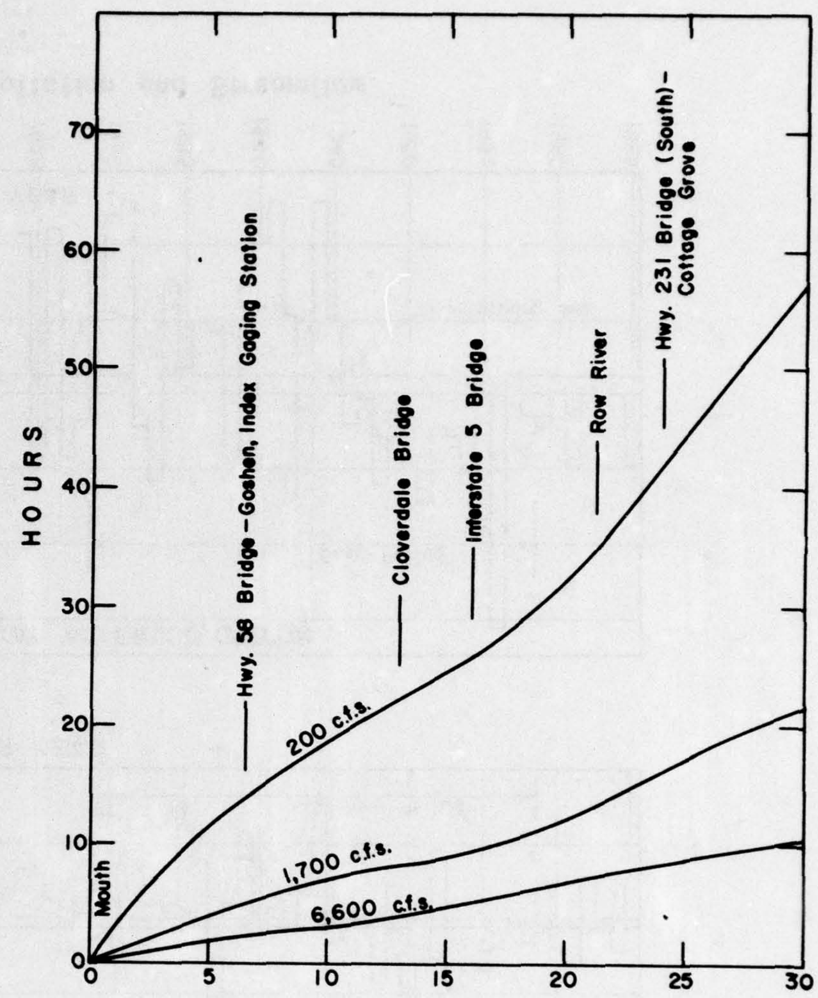


Figure 645. Time of Travel, Coast Fork Willamette River, Oregon
For Selected Discharges at Index Gaging Station

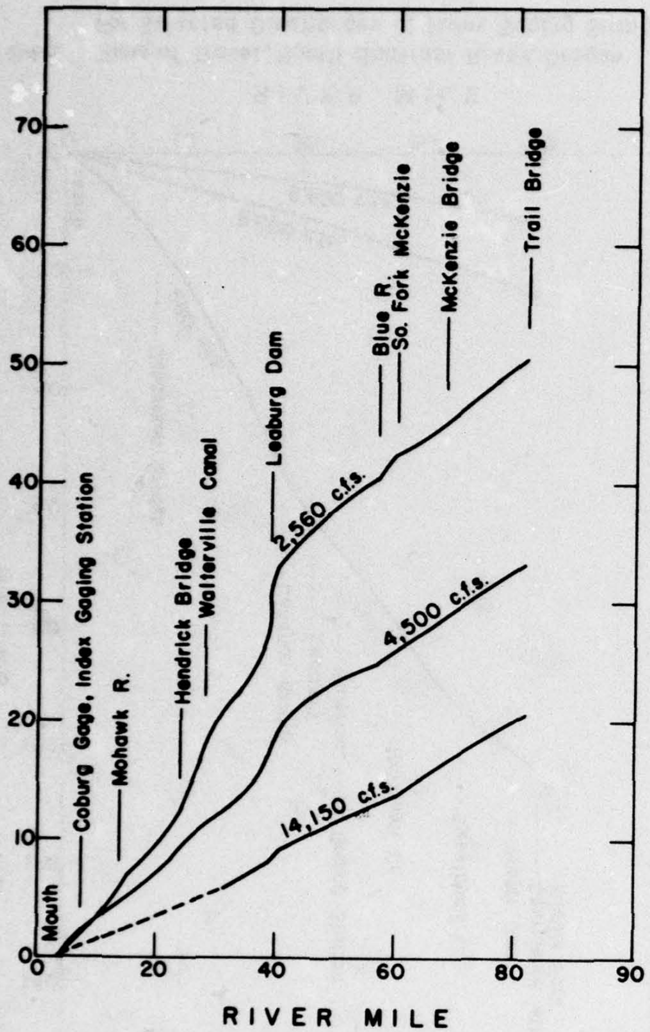


Figure 646. Time of Travel, McKenzie River, Oregon
For Selected Discharges at Index Gaging Station

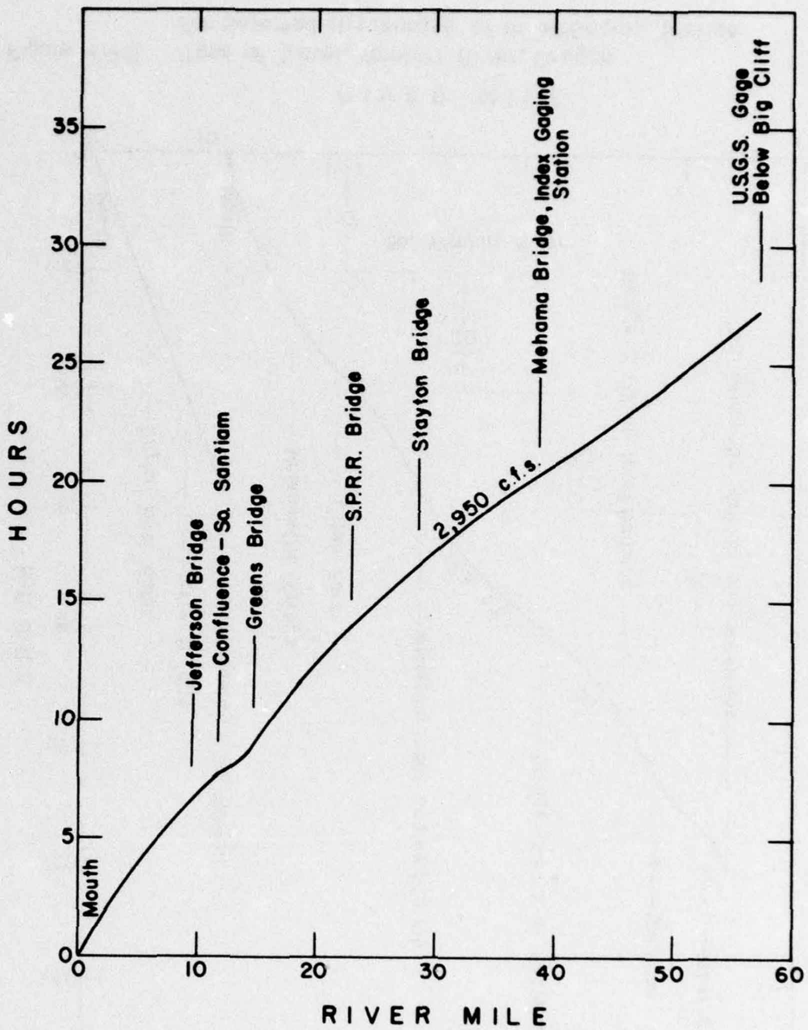


Figure 647. Time of Travel, North Santiam River, Oregon
For Selected Discharges at Index Gaging Station

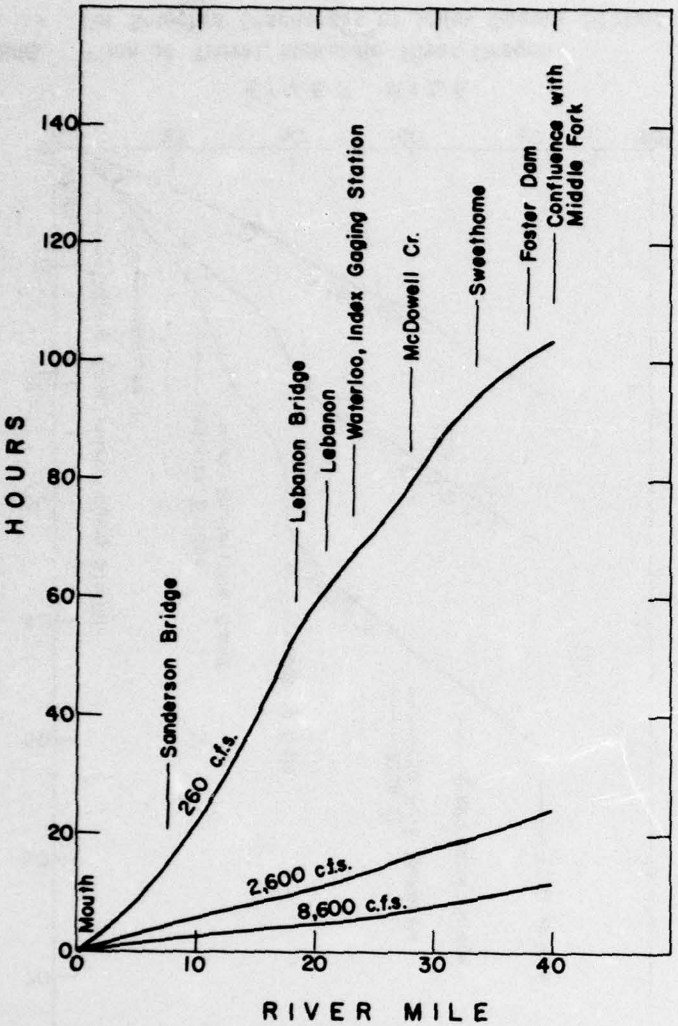


Figure 648. Time of Travel, South Santiam River, Oregon For Selected Discharges at Index Gaging Station

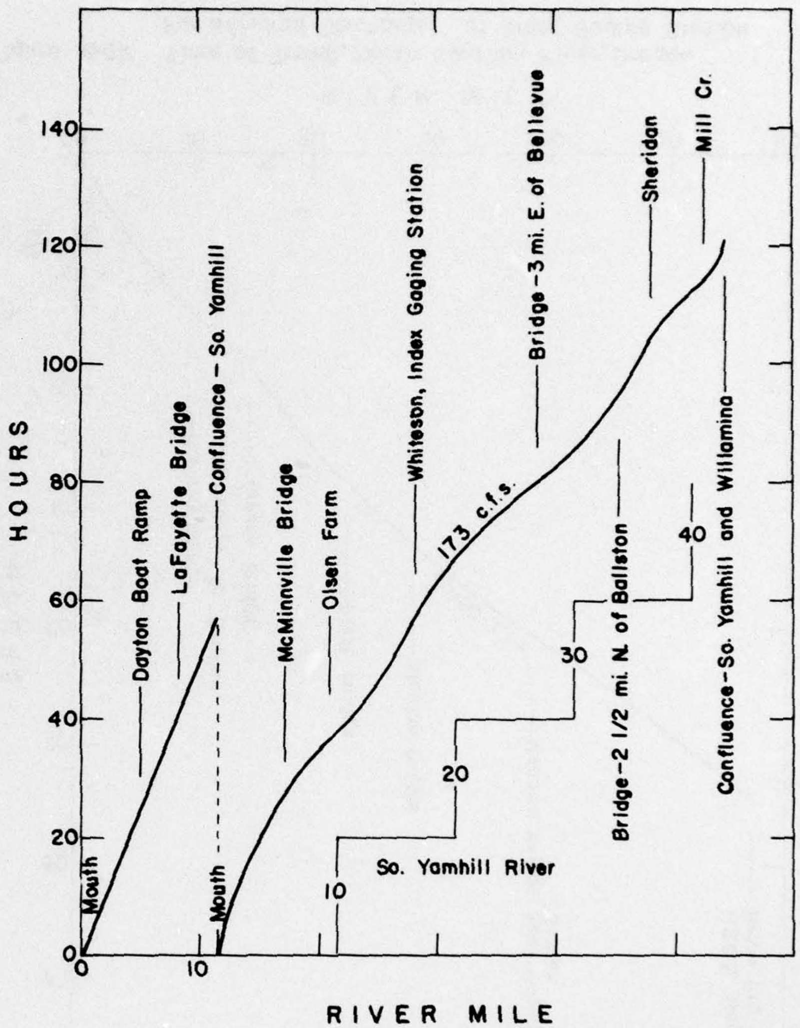


Figure 649. Time of Travel, Yamhill River, Oregon For Selected Discharges at Index Gaging Station

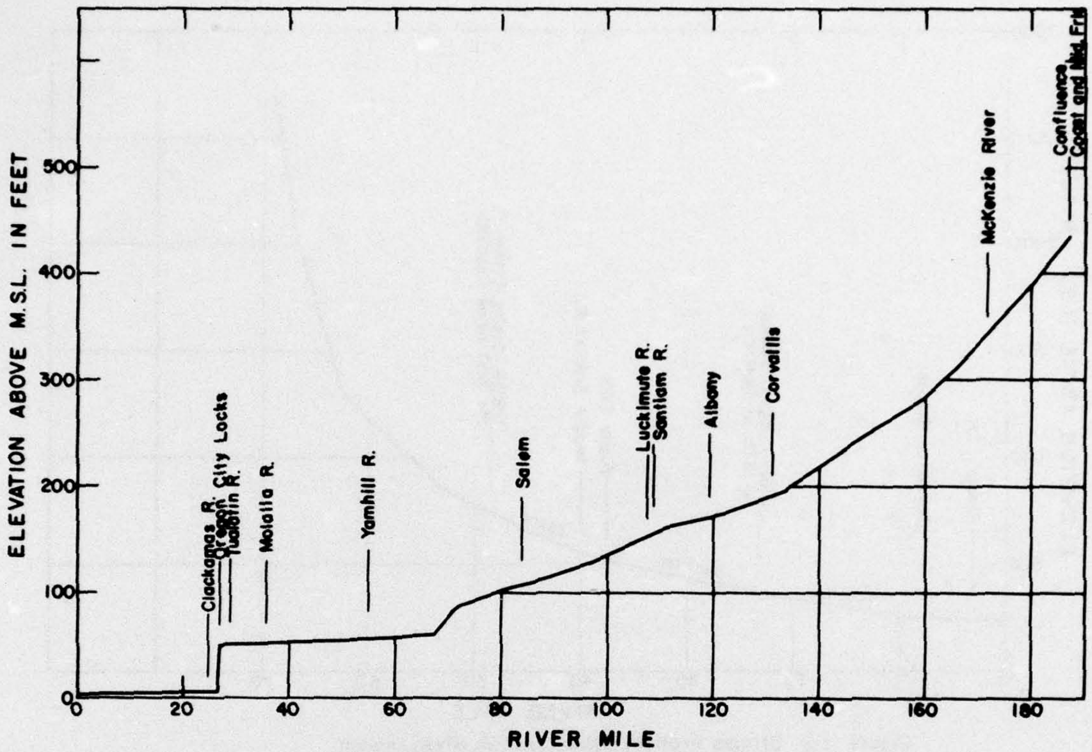


Figure 650 Stream Profile, Willamette River Main Stem

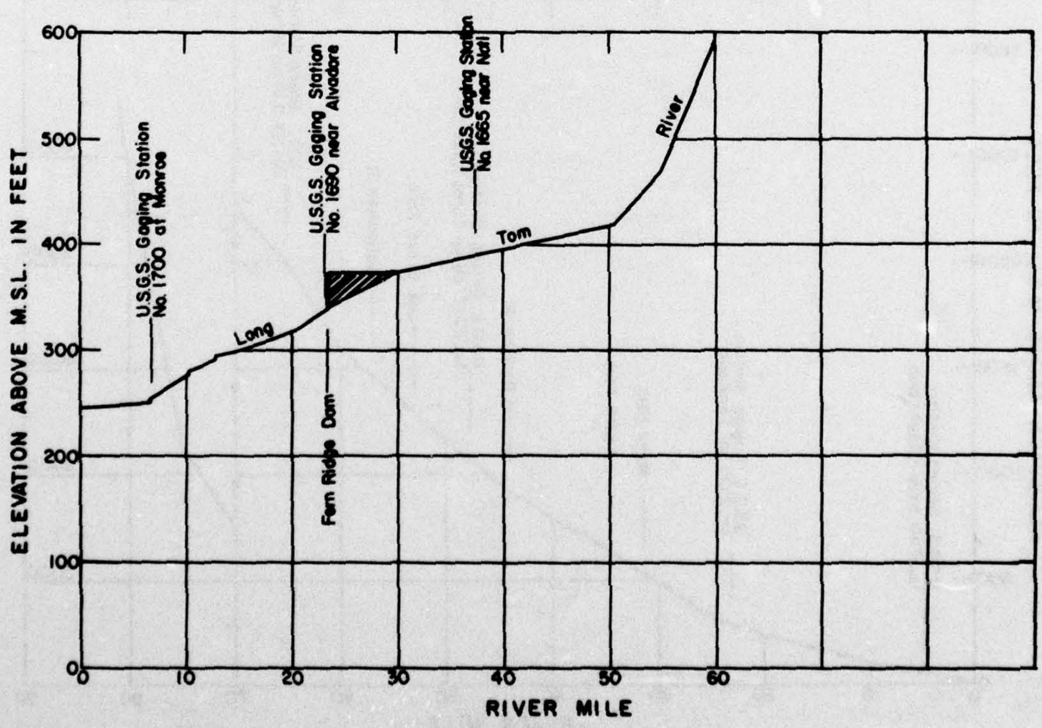


Figure 651 Stream Profile, Long Tom River, Oregon

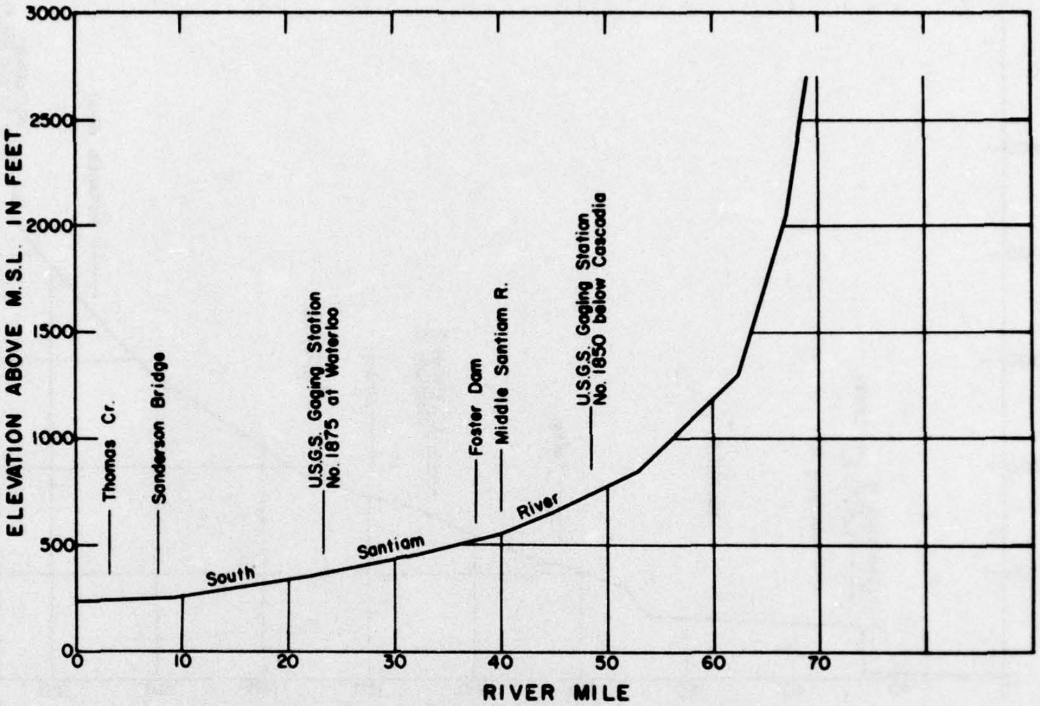


Figure 652 Stream Profile, South Santiam River, Oregon

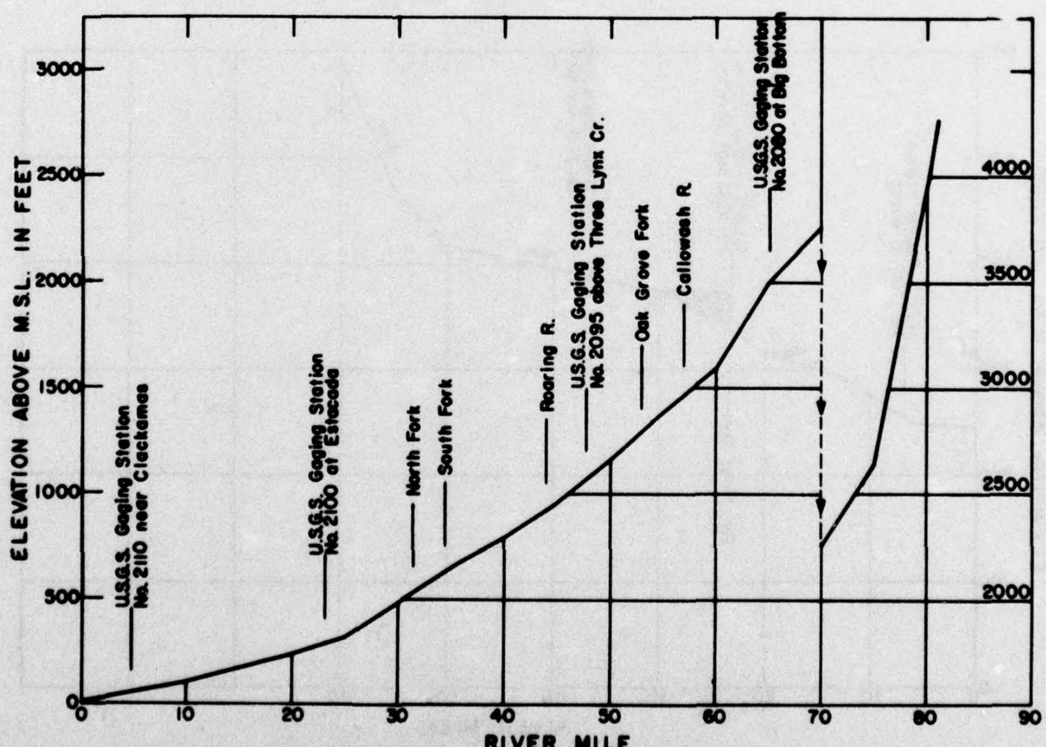


Figure 653 Stream Profile, Clackamas River, Oregon

Quality

The quality of water in Subregion 9 is generally good except for pollution at some points.

Chemical

The surface waters of the Willamette River Basin are the calcium magnesium bicarbonate type with these ions making up about 70 percent of the total dissolved ions. The dissolved-solids content of waters of most streams ranges from less than 40 mg/l to a maximum of about 85 mg/l. Hardness of water generally is less than 30 mg/l and in many areas less than 20 mg/l.

Some small streams on the valley plain that receive their base flow from terrace deposits, particularly the Willamette Silt, may contain dissolved solids in excess of 100 mg/l during low flow. The major streams draining the Coast Range are slightly more mineralized than those draining the Cascade Range, but the chemical composition is the same.

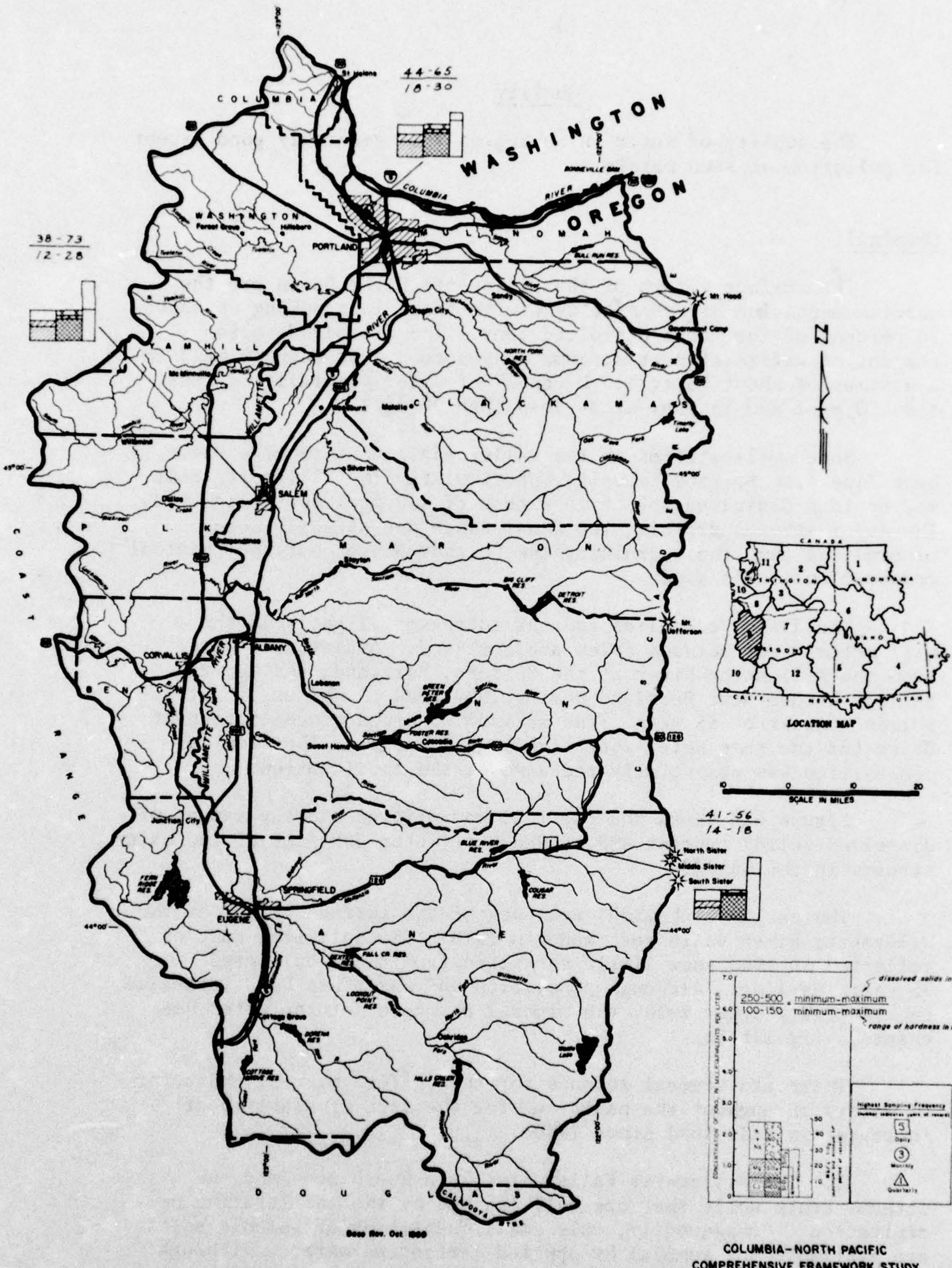
The dissolved-solids content increases slightly in the Willamette River between Salem and Portland. Analyses of water from the Willamette River at the Spokane, Portland, and Seattle Railway bridge near Portland during 1960 show a maximum dissolved-solids content of 65 mg/l. The maximum observed concentration at Salem for the same water year (1960) was 57 mg/l. The chemical composition was essentially the same at the two locations.

Figure 654 shows the chemical composition and the ranges of dissolved-solids content and hardness of water for some of the major streams in the basin.

The earliest chemical analyses of the surface waters of the Willamette River Basin were made in 1910. The data from samples collected in 1965 show little variation from those collected 55 years earlier. Although population and water use have increased substantially since 1910, the mineral character of the water has changed very little.

There are several reasons for the uniform mineral character of waters throughout the basin and for the lack of significant increases in salt load since 1910.

1. The Willamette Valley lies in a humid zone and the streams drain soils that are well leached by the infiltrating precipitation. Consequently, only small quantities of soluble salts are available for removal by applied irrigation water. Although the use of water for irrigation has increased continuously in the



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

WILLAMETTE SUBREGION 9

1968

FIGURE 654

Willamette Basin over the last 50 years, the increase in salt load from irrigation return flows has not been comparable to that experienced in other parts of the State, particularly east of the Cascades. In 1965, the salt contribution from irrigated acreage in the Willamette Basin was estimated to be 0.02 ton per acre per year. The total solute load from the basin has been estimated to be 0.28 ton per acre per year. (174)

2. Industrial use of water (largely confined to cooling and waste disposal) in the basin is primarily by the timber-resource and food-processing industries. The wastes contributed by these industries to the streams are mostly organic or insoluble and do not contribute substantially to the dissolved-mineral content of the water.

3. A study of the discharge records of streams in the basin over the past 40 years indicates a definite trend in the past 20 years towards above-average yearly runoff and higher minimum flows. Precipitation during the last 20 years has also been above the long-term average. Because maximum dissolved-solids content usually occurs during periods of low flow, any increase in salt load due to man's activity may have been somewhat masked.

At Salem for the period 1925-45, the yearly runoff averaged 15 million acre-feet and the average minimum flow was in the range of 3,000-3,500 cfs. For the period 1946-65, the average yearly runoff was more than 19 million acre-feet and the average minimum flow range was 4,000-4,500 cfs.

Streamflow in the Pacific Northwest historically has followed trends of relatively long periods of abundance or deficiency. The most recent period of above-average runoff (1945-65) has coincided with a period of accelerated economic growth and increased water use. Most of the major reservoirs in the basin were also constructed during this time. Because the period of higher runoff and the increased regulation occurred concurrently, the degree to which each has affected water-quality patterns in the basin cannot be accurately identified.

The surface waters of the basin are chemically suitable for most uses. All the streams in the basin for which data are available are suitable for domestic and municipal use. In certain parts of the lower reaches of some tributaries, and in the Willamette River, treatment is required to remove organic and bacterial contamination.

The surface water has low salinity and sodium hazards according to the rating method of the U.S.D.A. Salinity Laboratory staff (169-80) and is suitable for irrigation. Problems of water-quality deterioration due to irrigation return flow probably will not be significant in the future.

Surface waters in the basin are suitable for use by most industries. Industries that require waters of low silica content would have to use treatment because most streams have silica concentrations in excess of 10 mg/l. For some industrial uses, treatment would be required for turbidity and color.

Biological-Biochemical

The present quality of surface water in the Willamette Subregion is generally good, with the exception of high bacterial counts below areas of dense population. However, available water quality data and analyses also show that the quality is degraded during certain times of the year. For most water uses, the governing factor is the worst condition rather than the average. The critical period of water quality in the Willamette Subregion occurs in the summer and is of most concern.

Dissolved oxygen is a quality parameter that is indicative of the general condition of a stream. Low dissolved oxygen concentration normally indicates that the oxygen resources of a stream are being overtaxed by oxygen-demanding wastes. The Willamette River from its headwaters to Salem is a relatively shallow, fast moving stream. Dissolved oxygen concentrations range from 8 to 9 mg/l during the summer. However as the river moves downstream, its flow characteristics change, demands for waste assimilation increase, and the dissolved oxygen levels fall. Finally, in Portland harbor average summer concentrations range from 3 to 4 mg/l, with some minimum daily values of less than 2 mg/l of dissolved oxygen. Progressive degradation in oxygen content in the Willamette River is shown in figure 655, indicating both seasonal variations and changes with respect to distance from the mouth of the river.

Most tributary streams maintain dissolved oxygen levels of at least 80 percent saturation throughout the summer months. However, the South Santiam and Tualatin Rivers and Rickreall Creek experience major depressions in oxygen level. Minimum summer levels on the South Santiam below Lebanon have dropped occasionally to less than 1 mg/l dissolved oxygen.

Bacteriological quality of the Willamette below Springfield is highly variable but generally unsuitable for water-contact recreation. Total coliform densities range from 1,000 to 50,000 organisms/100 ml, with occasional maximums as high as 70,000. The accompanying figure 656 illustrates coliform densities during the summers of 1963 and 1965. It should be noted that bacterial levels generally exceed 1,000 organisms/100 ml, the recommended standard for water-contact sports. Tributary streams within the subregion have excellent bacteriological quality in upper reaches but generally exhibit poor quality in the lower reaches and are unsatisfactory for

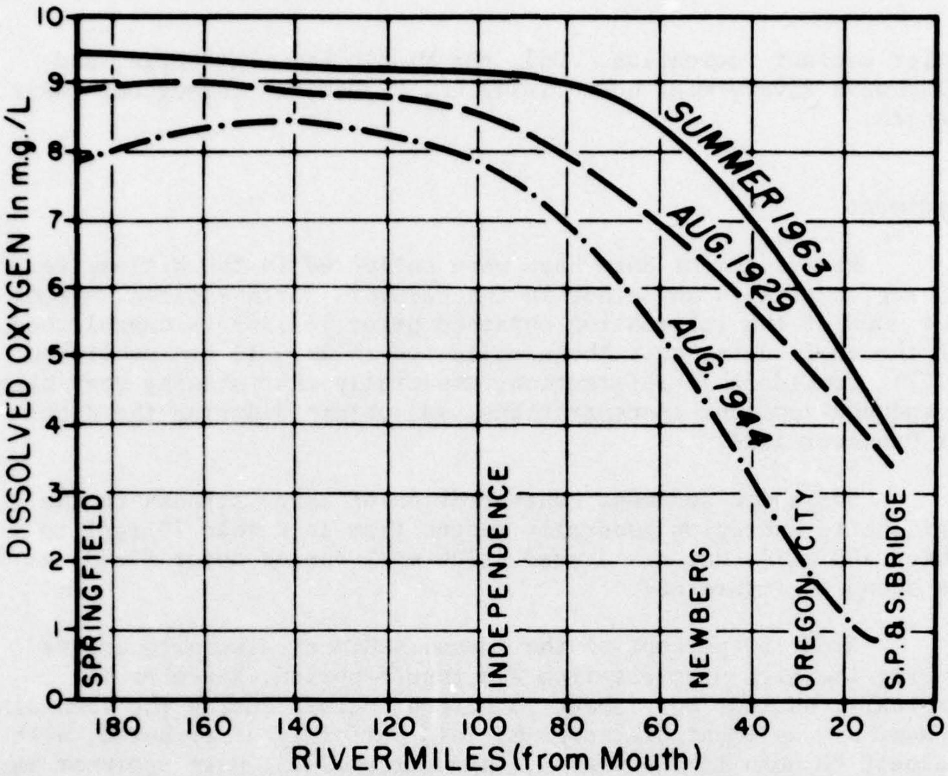


FIGURE 655. Dissolved Oxygen, Percent Saturation.

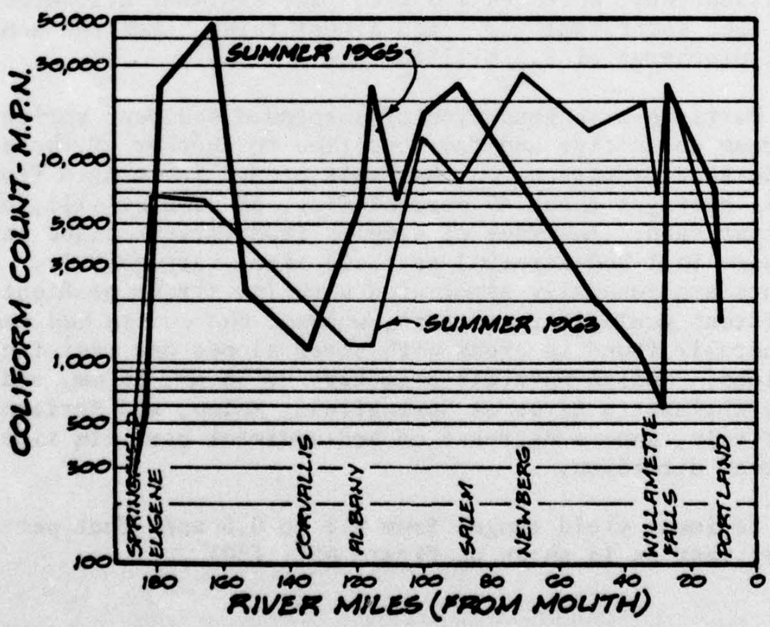


FIGURE 656. Coliform Bacteria Densities.

water-contact recreation. Only the Middle Fork, McKenzie, and Clackamas Rivers meet bacteriological objectives throughout their length.

Sediment

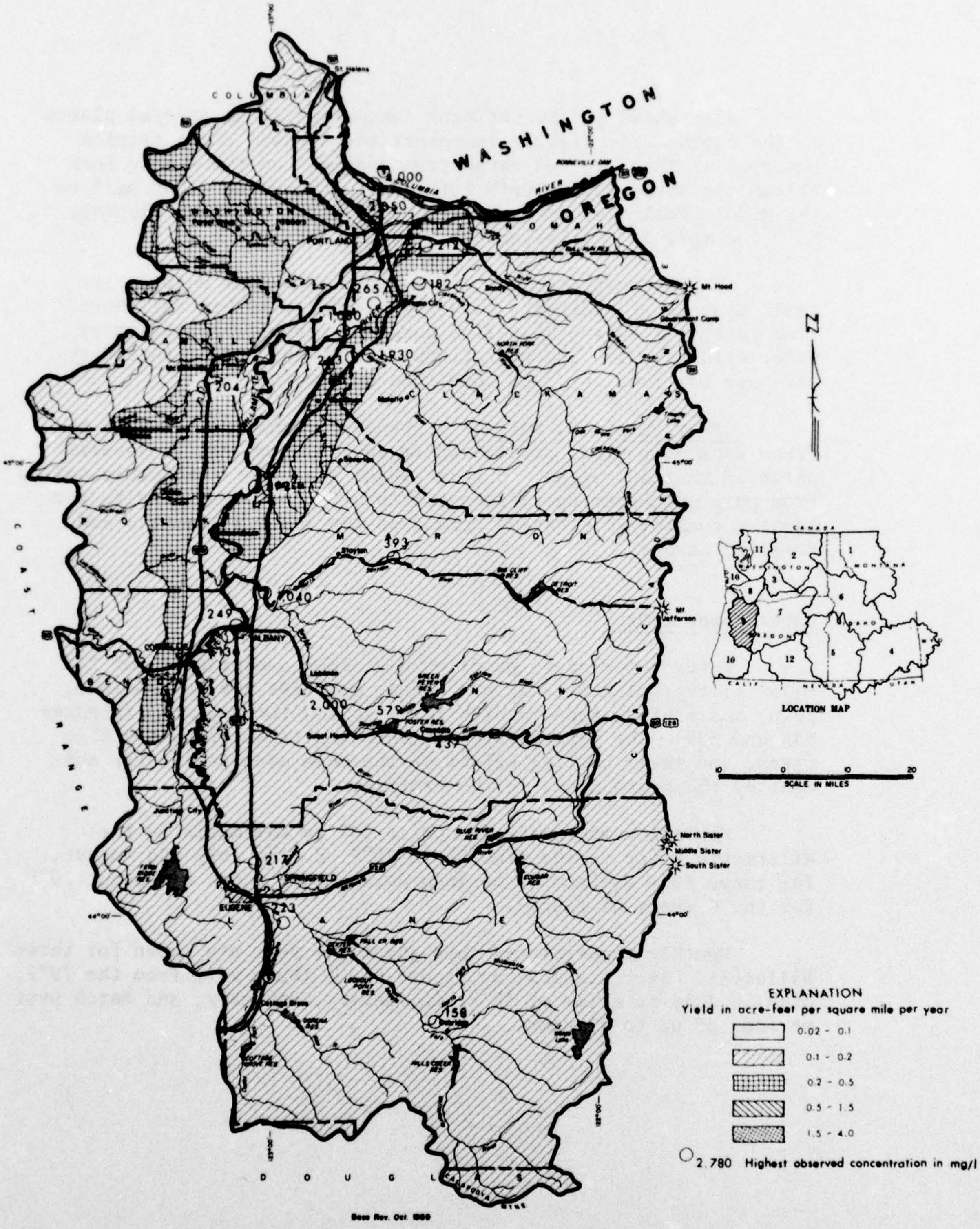
More sediment data have been collected in the Willamette Subregion than in any other in the Columbia-North Pacific Region; but much of the information obtained prior to 1962 is unpublished. Of the early data, only those collected in 1910-12 are published. (177) Considerable information, especially that showing very high suspended-sediment concentrations, was obtained during the flood of December 1964.

Suspended-sediment concentration of large streams in the Willamette Subregion generally ranges from less than 10 mg/l to about 400 mg/l, but can exceed 2,000 mg/l during major floods as is shown on figure 657.

About 80 percent of the annual sediment discharge occurs during the high precipitation and runoff period, November to February, whereas only about 20 percent occurs during the remaining 8 months. Sediment discharge is less uniformly distributed, with respect to both time and area, than streamflow. More sediment may be discharged by one flood than is discharged during several average years. For instance, during the period December 21-31, 1964, the total sediment discharge of the Willamette River at Portland was 6.6 million tons, which is 1.5 times the sediment discharge of the entire 1963 water year (127) and almost three times the annual average discharge of 2.3 million tons.

Particle-size gradation of suspended sediment varies from one stream to another and from one time to another at the same site. Particle-size gradation, on the basis of available data from several streams, averages about 45 percent clay, 38 percent silt, and 17 percent sand. Analyses of samples from various sites in the basin show that bed-material particle sizes vary greatly. Fine bed sediments are generally associated with low stream gradients and nonresistent geologic formations, whereas the coarse bed sediments are generally found in areas with steep slopes and resistant rock formations. Median particle diameters of 55 mm, 16 mm, and 0.6 mm for the Willamette River at Springfield, Salem, and Portland, respectively, show a decrease of bed-sediment particle size in the downstream direction.

Sediment yield ranges from 0.1 to 0.5 acre-foot per square mile per year as is shown on figure 657. (30)



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

WILLAMETTE SUBREGION 9

1968

FIGURE 657

Also shown is the sediment concentration at several places in the basin. The figures represent the highest concentration observed at the site and range from 158 mg/l on the Middle Fork Willamette River below North Fork near Oakridge to 2,050 mg/l on the Middle Fork Willamette River below North Fork near Oakridge to 2,050 mg/l on the Willamette River at Portland.

Whereas most streams in the basin transport relatively small amounts of sediment, they are generally turbid for short time intervals during high-flow periods. Industries requiring water with very low concentrations of sediment and/or turbidity may have to treat water at some time during the year.

Other Suspended Solids Suspended organic matter such as fiber from pulp mills creates water quality problems in several parts of this subregion. Such material and other settleable solids from pulp and paper operations add to bottom sludge deposits and exert a considerable oxygen demand on the lower Willamette and Portland harbor.

Water Temperature

Water temperature profiles have been constructed for 240 miles of the Willamette River. These profiles are for maximum, mean, and minimum temperatures for July and for August. (figures 658 and 659) The temperatures of entering tributaries are also given, and their cooling effect on the main stem is clearly evident by the sharp drops in the profile.

Maximum temperature from mile 240 to the mouth in the Willamette River varied from 65 to 79°F. during July and August. The range from minimum to maximum during each month was about 20°F. for the 9 years of record.

Monthly temperatures throughout the year are shown for three Willamette River stations on figure 660. These vary from the 79°F. high in July to a low of 32°F. in January, February, and March over periods of up to 12 years.

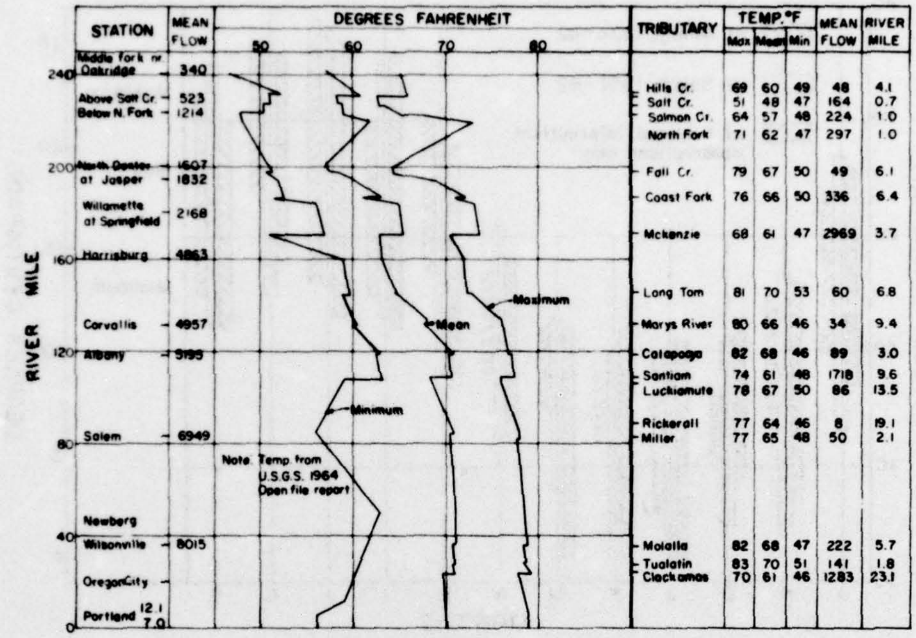


Figure 658 Water Temperature Profile for July, Willamette River Basin, 1954-62

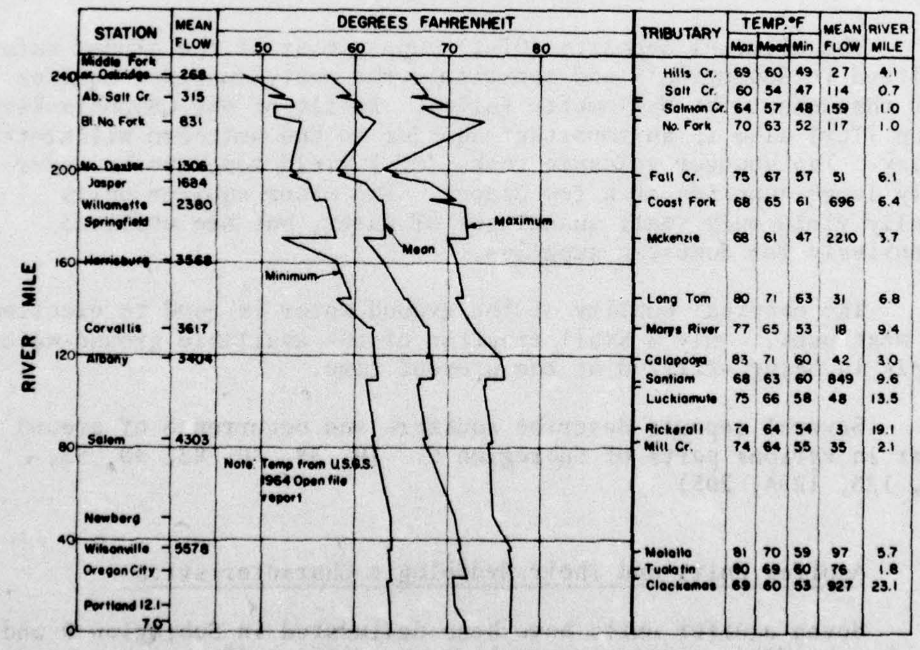


Figure 659 Water Temperature Profile for August, Willamette River Basin, 1954-62

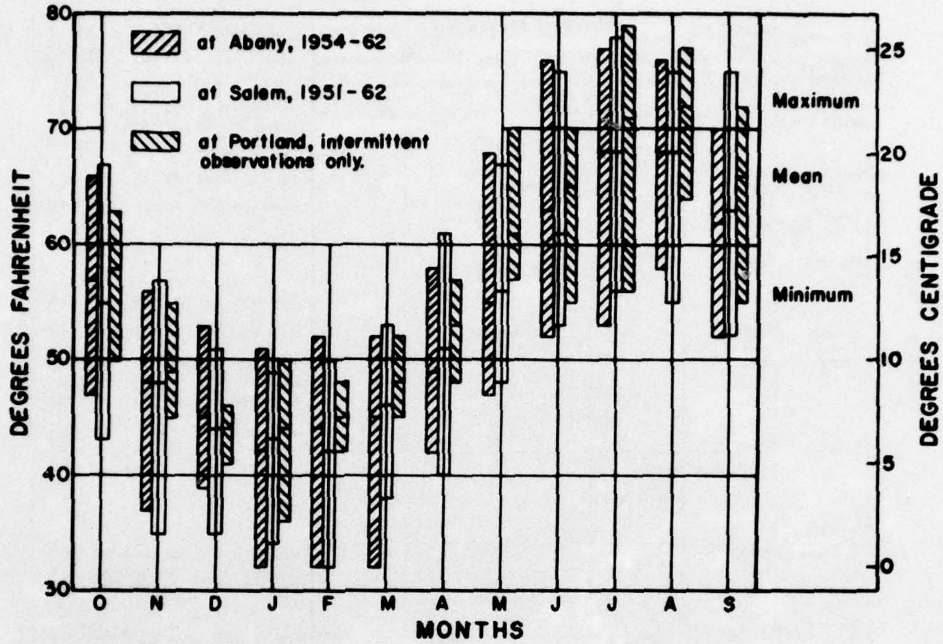


Figure 660 Monthly Water Temperatures, Willamette River

GROUND WATER

The alluvial deposits (QTal) supply most of the ground water utilized in Subregion 9 and constitute the most important aquifer unit throughout the Willamette Valley. Basalt of the Columbia River Group (Tcr) also is an important aquifer in the northern Willamette Valley. The younger volcanic rocks (QTv) yield moderate to moderately large supplies at a few places. The other aquifer units usually yield only small quantities of water, but are utilized extensively for domestic supplies.

The chemical quality of the ground water is good to excellent for most uses. Only a small fraction of the available ground-water supply is being utilized at the present time.

Several reports describe aquifers and occurrence of ground water in various parts of Subregion 9. (9, 38, 40, 43, 48, 53, 118, 123, 125A, 205)

Aquifer Units and Their Hydrologic Characteristics

Seven aquifer units have been delineated in Subregion 9 and are shown in figure 661. Generally, the units conform to those used in the Willamette Basin Type 2 study which is based on maps of Wells and Peck (202), and Peck and others (116).

The alluvial deposits of Quaternary and late Tertiary age (QTal) underlie most of the Willamette Valley lowland. The unit includes Holocene alluvium, largely sand and gravel, underlying present flood plains; the Willamette Silt of late Pleistocene age; older alluvium (Pleistocene) which crops out in terraces and benches, but also underlies the Holocene alluvium; and the Troutdale Formation and similar deposits of Pliocene age. These latter deposits consist of coarse-grained alluvial stream-channel and fan deposits and fine-grained lacustrine deposits. These formations crop out in high benches and, at many places, underlie both the older and the Holocene alluvium. The older terrace deposits and the Troutdale Formation have been weathered to depths exceeding 50 feet at many places, greatly reducing the permeability.

The Troutdale Formation, some of the older alluvial deposits and the Holocene alluvium include considerable thicknesses of fine-grained materials of low permeability, but also contain lenses and beds of medium to coarse-grained sand and gravel that are permeable and yield moderate to large quantities of water to wells. Yields of a few hundred to more than 1,000 gpm are common. The Willamette Silt, which occurs as a widespread blanket about 50 to 100 feet thick throughout the Willamette Valley, is predominantly fine grained and yields only small quantities of water to wells. However, it is very porous and has a high specific yield (123-29 and 64); consequently, it is important in storing and transmitting ground water downward to recharge more permeable deposits beneath it.

The younger volcanic rocks (QTv) include basaltic and andesitic lavas and pyroclastic rocks that were extruded in late Tertiary and Quaternary time to form the High Cascade Range. Small areas of similar rocks (Boring Lava) crop out in the northern Willamette Valley. That these materials in the High Cascade Range are highly porous and permeable is evidenced by the discharge characteristics of streams draining them. However, they have been explored only by a few small wells drilled at recreational sites. The Boring Lava in the northern Willamette Valley consists of only one to a few flows, and usually is mostly or entirely above the water table. Generally, only small to moderate yields are obtained from the thin zone of saturation in the unit.

The Sardine Formation (Tsf) of Miocene age crops out over large areas on the western slope of the Cascade Range. The formation consists chiefly of andesitic lavas, breccia, agglomerate, and tuff. At most places it is several thousand feet thick. The lavas are fractured and jointed, and the pyroclastic and sedimentary strata are only moderately compacted and cemented so that the

unit, as a whole, has fair porosity and permeability and yields small to moderate quantities of water at most places. A thick weathered zone stores large quantities of water and yields small supplies to dug and shallow drilled wells.

Basalt of the Columbia River Group (Tcr) of Miocene age consists of one to several flows which have low internal permeability but, at places, have moderate permeability and transmissibility in zones at the contacts between successive flows. Wells penetrating a few hundred feet of basalt generally have moderate to moderately large yields. The basalt crops out chiefly in rounded hills flanking the Willamette Valley in the northern half of the subregion, and is encountered at varying depths beneath the Troutdale Formation or younger deposits at many places in the valley.

The Little Butte Volcanic Series (Tlbv) consist of andesitic and basaltic lava flows and pyroclastic rocks forming a sequence 5,000 to 10,000 feet thick on the western slope of the Cascade Range. The rocks have been altered, compacted, and cemented so that they have low to moderately low porosity and permeability. A deep weathered zone yields small quantities of water to dug wells, and furnishes base flow to streams draining the unit. Drilled wells obtain water from the base of the weathered zone and from fractures in the rock. Yields generally are small to moderate, rarely exceeding 100 gpm.

The older Tertiary volcanic rocks (Tov) are a heterogeneous group of lavas, pyroclastic rocks, and interbedded marine and nonmarine sedimentary rocks, mainly of Eocene and Oligocene age, that crop out on the west side of the Willamette Valley, chiefly in the Coast Range. Little of the original porosity and permeability remain; ground water is contained in, and moves through, joints and other fractures and soil and subsoil. Yields of both dug and drilled wells are small. A thick weathered zone stores a large quantity of ground water and maintains the base flow of streams.

The marine sedimentary strata of Tertiary age (Tm) includes several formations of Eocene and Oligocene age which crop out chiefly in the Coast Range, but also in scattered low hills on the east side of the Willamette Valley. The unit underlies much of the valley at depths ranging from a few to several thousand feet. The rocks have been compacted and cemented so that they have low porosity and permeability. Well yields generally are small. The weathered zone developed on these rocks generally is thinner than on the volcanic rocks and consequently yields less water to the base flows of streams draining the unit.

Table 360 - Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 9

Map Symbols and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
QTal: Alluvial deposits underlying present flood plains, terraces, and benches; some slack-water deposits. Pleistocene, late Pliocene in age.	Stream channel, delta, and fan deposits are chiefly sand and gravel. Flood-plain and slack-water deposits are fine to medium sand, silt, and clay. Some sands and gravels are lightly to moderately cemented.	Generally porous and permeable. Coarser deposits yield large quantities of water to wells where a thickness of 50 or more feet is saturated. Major aquifer in subregion, with great potential for increased development.	Dissolved solids less than 500 mg/l, generally less than 300 mg/l; water soft to moderately hard; excessive iron in some wells.
QTv: Boring Lava, and similar lavas and pyroclastic rocks of Quaternary, late Tertiary age.	Basaltic and andesitic lava flows. Basalts generally open textured, with interconnected voids. Includes breccia and pyroclastic rocks ranging from scoria to ash.	Generally porous and permeable. Important for ground-water storage in mountains, maintains high base flow of streams. Wells probably will yield moderate to large quantities of water.	Generally low dissolved solids; soft to moderately hard water.
Tsf: Sardine Fromation; includes upper part of Breitenbush Series and Rhododendron Fm. of Hodge. Middle and late Miocene in age; includes some intrusive rocks.	Andesitic lava flows, flow breccia, tuff breccia, tuff, and conglomerate. Flows average about 30 feet thick, platy jointing common. Pyroclastic rocks massive, generally coarse.	Moderate porosity and permeability in interstitial voids and joints. Yields small to moderate supplies of water to wells. Important in storage of ground water for maintaining base flow of streams.	Dissolved solids generally less than 500 mg/l; water soft to hard; excessive sodium, boron, fluoride rare.
Tcr: Basalt of the Columbia River Group. Middle Miocene in age.	Dark, fine-grained, thick, columnar-jointed basalt flows; interbeds rare. Individual flow 25 to 100 feet thick; unit a few to about 1,500 feet thick.	Porosity and permeability of individual flows low; water moves through zones at and near contact of successive flows, interflow zones. Well yields range from small to moderately large.	Dissolved solids generally less than 400 mg/l; water generally soft to moderately hard. High silica; sodium adsorption ratio rarely exceeds 5.
Tlbv: Little Butte Volcanic Series, (Peck and others, 1964). Oligocene and early Miocene in age.	Thick sequence of andesitic to basaltic flows, flow breccias and pyroclastic rocks. Some granodiorite and diorite intrusives.	Water occurs in joints and other fractures and in deeply weathered soil and subsoil. Wells yield small to moderate supplies (to 100 gpm). Relatively low base flow streams.	Dissolved solids generally less than 500 mg/l, except where contaminated by saline water from marine strata.
Tov: Lavas and interbedded pyroclastic and clastic rocks. Includes Nestucca and Fisher Fm., and Tillamook and Siletz River Volcanics. Tertiary, chiefly Eocene in age.	Interbedded lava flows, flow breccia, pumice, tuff and marine sedimentary rocks including sandstone, shale, mudstone. Includes some intrusive rocks.	The rocks have been altered and mineralized. Water occurs in joints and other fractures. Well yields are small, rarely moderate. Deeply weathered granular soil forms a fair storage reservoir for maintaining low flow of streams.	Dissolved solids generally less than 500 mg/l but water saline at a few places. Excessive arsenic in some wells south of Eugene. Water generally moderately hard to hard.
Tm: Marine sedimentary strata of Tertiary age. Basaltic dikes and sills intruded into sediments are also included.	Sandstone, shale, and mudstone, commonly tuffaceous, thin to massive bedded. Dikes, sills, flows, and pyroclastic rocks of basaltic composition in some areas.	Rocks have been cemented, compacted, altered, and mineralized so that little primary porosity remains. Well yields generally low. Clayey soil and subsoil form poor reservoir for ground-water storage. Base flow of streams is low.	Shallow water low dissolved solids; moderately hard to hard. Saline water common at depth.

A summary description of the aquifer units, their general hydrologic characteristics, and the quality of water yielded by them are given in table 360. The availability of ground water is shown on a map, figure 662. For maximum utility, that map and the aquifer-unit map, figure 661, should be used together.

Water in Storage

A rough estimate of the quantity of water stored in the uppermost 50 feet of each aquifer unit is given in table 361.

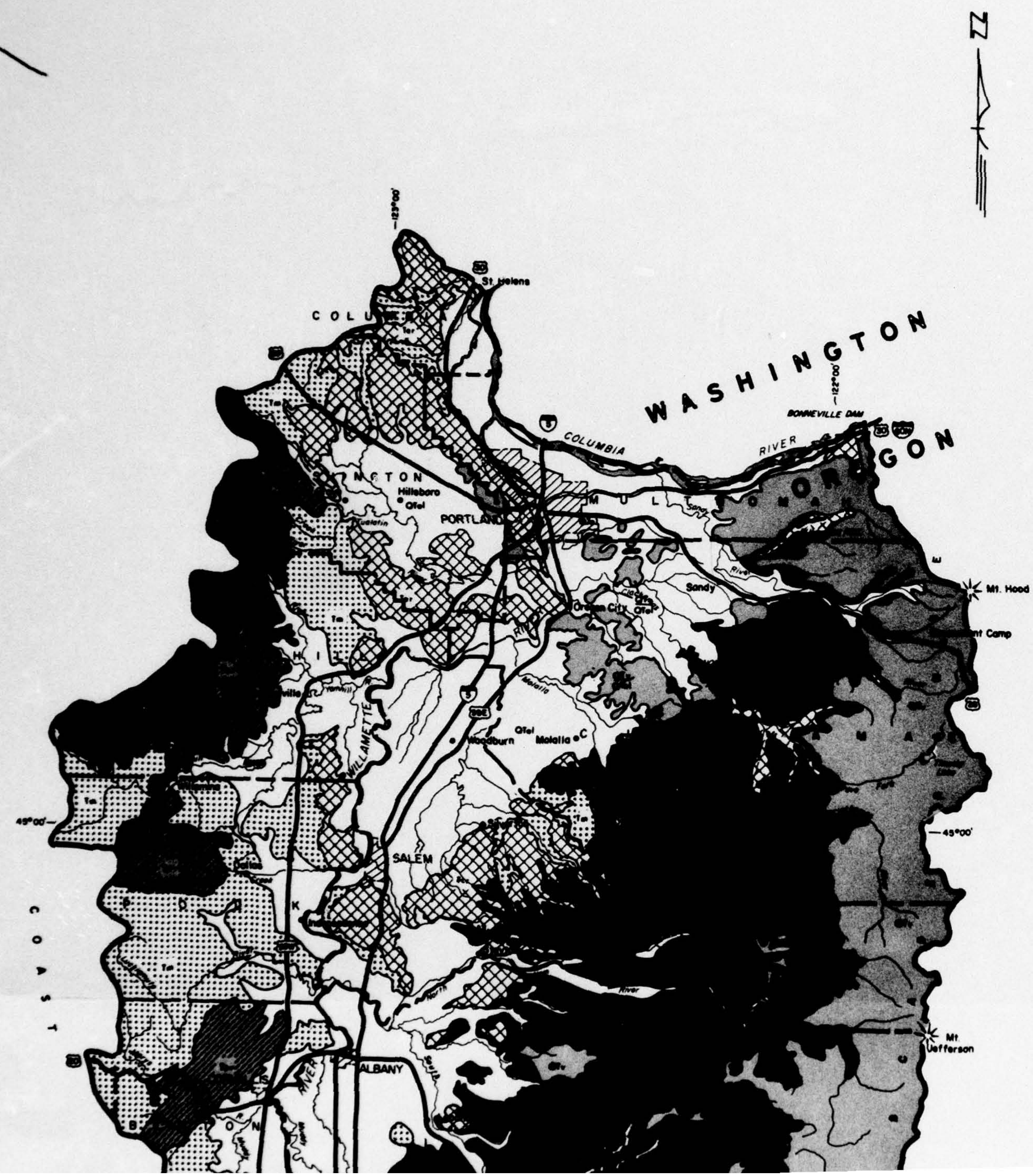
A specific yield of 20 percent was estimated for the alluvial-aquifer unit (QTal). The younger volcanic rocks (QTv) include moderately porous lavas and large quantities of very porous pyroclastic rocks; the estimated specific yield of 5 percent is believed to represent a minimum. A specific yield of 5 percent also was estimated for the Sardine Formation (Tsf) which includes large quantities of moderately porous pyroclastic rocks.

The specific yield of the unweathered rock of the Columbia River Group (Tcr), the Little Butte Volcanic Series (Tlbv), and the older volcanic rocks (Tov) is believed to be less than 1 percent. However, the weathered zone, which has a considerably higher specific yield, is deep on all of these units. An average specific yield of 2 percent was estimated for the upper 50 feet of the saturated zone which is partly in weathered, and partly in unweathered, rock.

The zone of weathering on the marine sedimentary strata (Tm) generally is thinner than on the volcanic rocks and the average specific yield probably is somewhat less. A value of 1 percent was used for that unit.

Table 361. Storage, Recharge, and Discharge of Ground Water in Aquifer Units in Subregion 9

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge	
	Sq. Mi.	Acres (1000's)	Specific Yield (percent)	Depth Used (ft)	Water (1000's ac-ft)	Inches over area	(1000's ac-ft)
QTal	2,750	1,760	20	50	17,600	18	2,640
QTv	2,250	1,440	5	50	3,600	48	5,760
Tsf	2,018	1,290	5	50	3,200	12	1,290
Tcr	760	486	2	50	490	6	243
Tlbv	2,102	1,350	2	50	1,350	6	675
Tov	880	564	2	50	560	4	188
Tm	1,130	724	1	50	360	4	240
TOTAL (rounded)	11,900	17,614			27,000		11,000



LOCATION MAP

EXPLANATION

QTal

Alluvial deposits of Pleistocene and late (?) Pliocene age.

Yields small to large supplies of water from sand and gravel; quantity is related to saturated thickness.

Dissolved solids < 500 mg/l, water soft to moderately hard. Excessive iron in some wells. A few wells yield mineralized water that migrated from deeper strata.

Basaltic and andesitic lava and pyroclastics of Quaternary and late Tertiary age.

Important reservoir aquifer in headwaters area; probably will yield moderate to large amounts of water.

Dissolved solids low, water soft to moderately hard.

Andesitic lavas and pyroclastics of the Sardine formation of Miocene age.

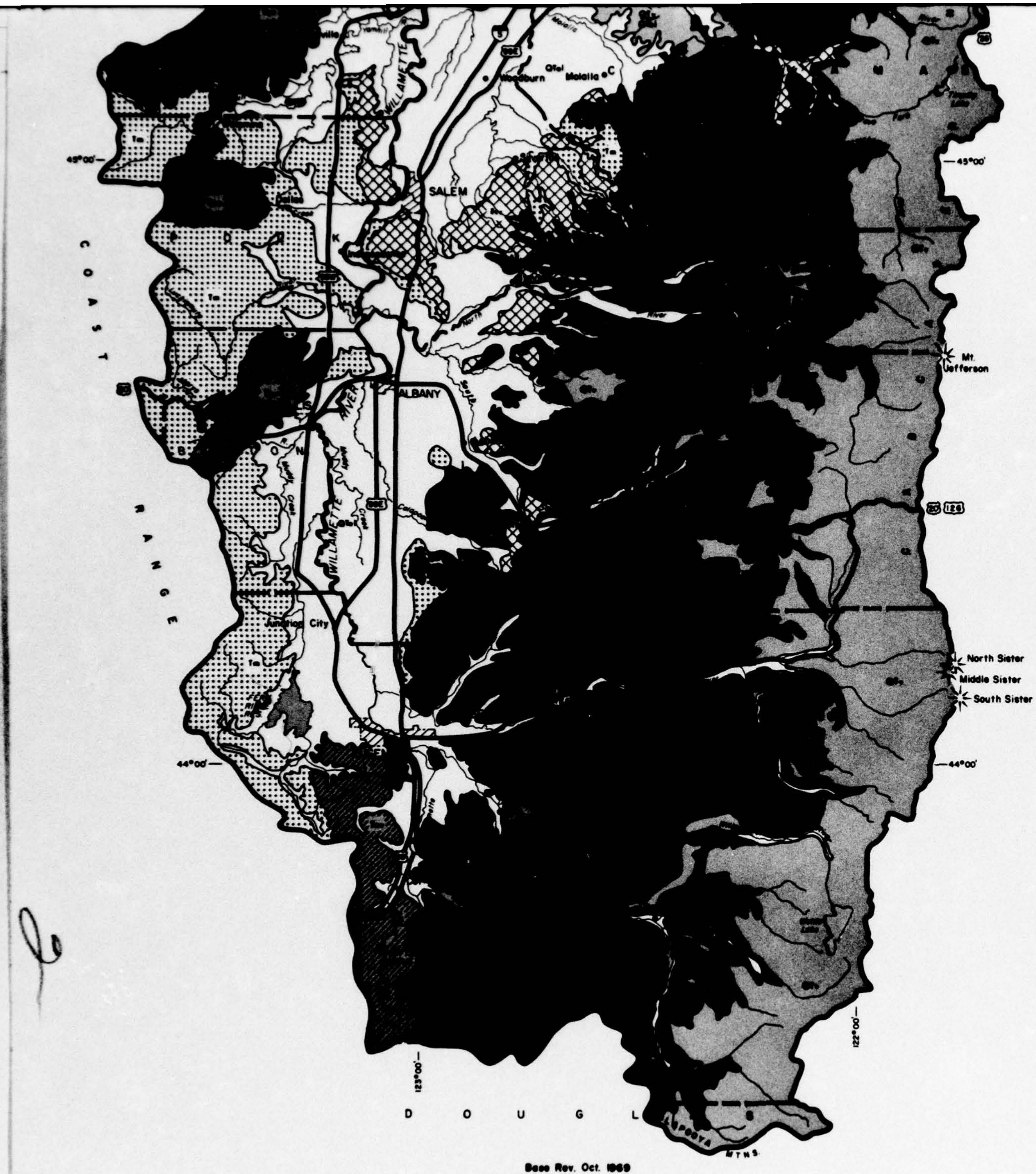
Important aquifer in headwaters area. Yields small to moderate supplies.

Dissolved solids generally low, water soft to hard.

Tcr

Basalt of the Columbia River Group of Miocene age.

Yields small to large supplies, depending partly on thickness penetrated.



Yields small to large supplies of water from sand and gravel; quantity is related to saturated thickness.

Dissolved solids < 500 mg/l, water soft to moderately hard. Excessive iron in some wells. A few wells yield mineralized water that migrated from deeper strata.

Basaltic and andesitic lava and pyroclastics of Quaternary and late Tertiary age.

Important reservoir aquifer in headwaters area; probably will yield moderate to large amounts of water.

Dissolved solids low, water soft to moderately hard.

Andesitic lavas and pyroclastics of the Sardine formation of Miocene age.

Important aquifer in headwaters area. Yields small to moderate supplies.

Dissolved solids generally low, water soft to hard.

Tcr

Basalt of the Columbia River Group of Miocene age.

Yields small to large supplies, depending partly on thickness penetrated.

Dissolved solids generally < 400 mg/l. A few wells yield mineralized water that migrated from marine strata.

Andesitic and basaltic volcanics of the Little Butte Volcanic series of Oligocene and Miocene age.

Generally low porosity and permeability; yields small to moderate supplies.

Dissolved solids < 500 mg/l except where contaminated by migrated mineralized water.

Older Tertiary volcanic lavas and pyroclastics, undifferentiated.

Porosity, permeability generally low, generally yields only small supplies.

Dissolved solids low, water quality satisfactory except where contaminated by migrated mineralized water. Water from a few wells west and south of Eugene has excessive arsenic.

Tm

Marine sedimentary strata of Tertiary age.

Low porosity and permeability, generally yields only small supplies.

Shallow water generally low dissolved solids; saline water common at depth, may occur < 100 feet below surface.

Where a surficial aquifer overlies one or more aquifers that also furnish significant amounts of water as, for example, where Quaternary alluvial deposits overlie Tertiary sedimentary rocks, the relation is indicated by the map symbols, $\frac{Qal}{Ts}$.

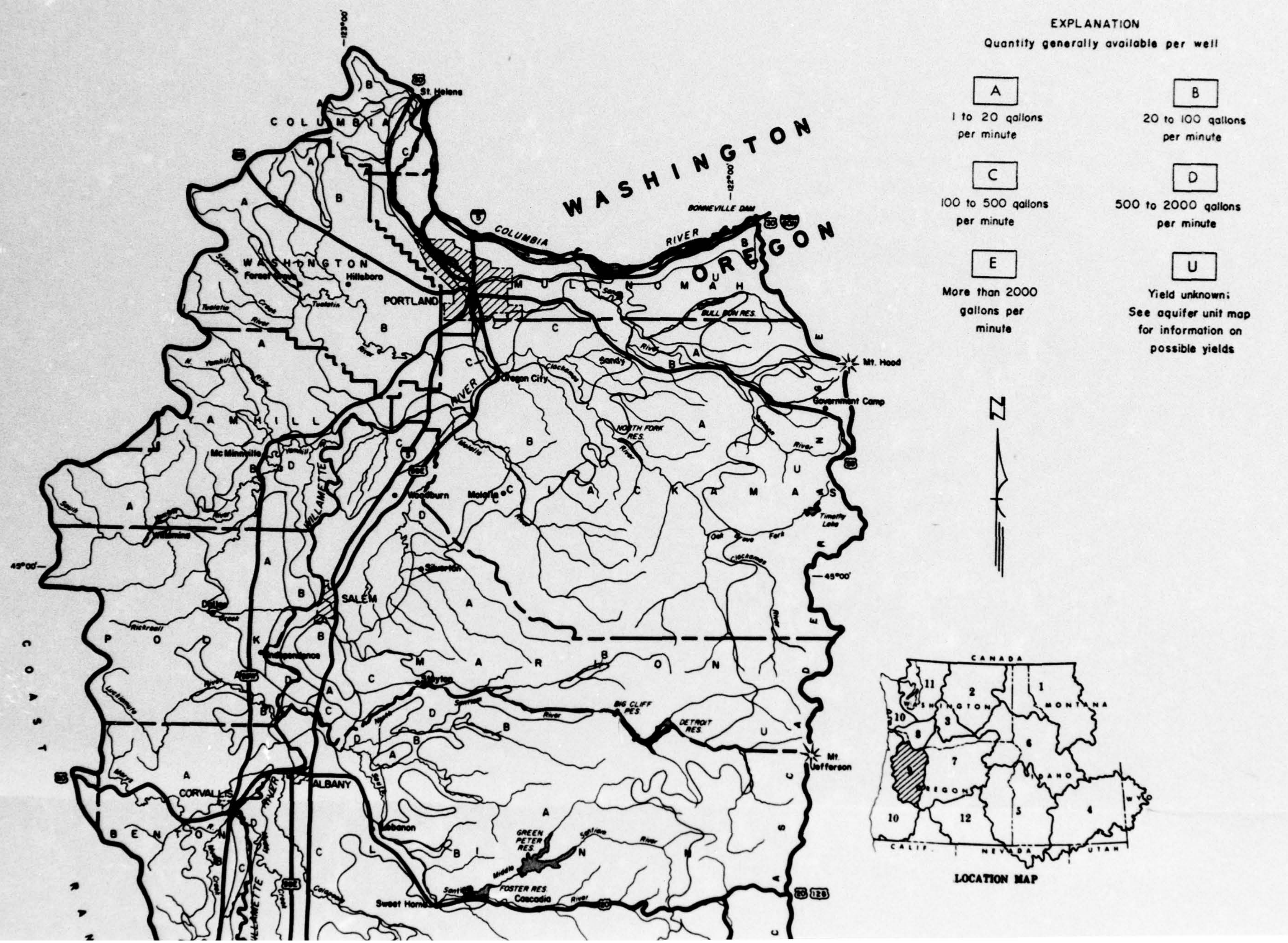
COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

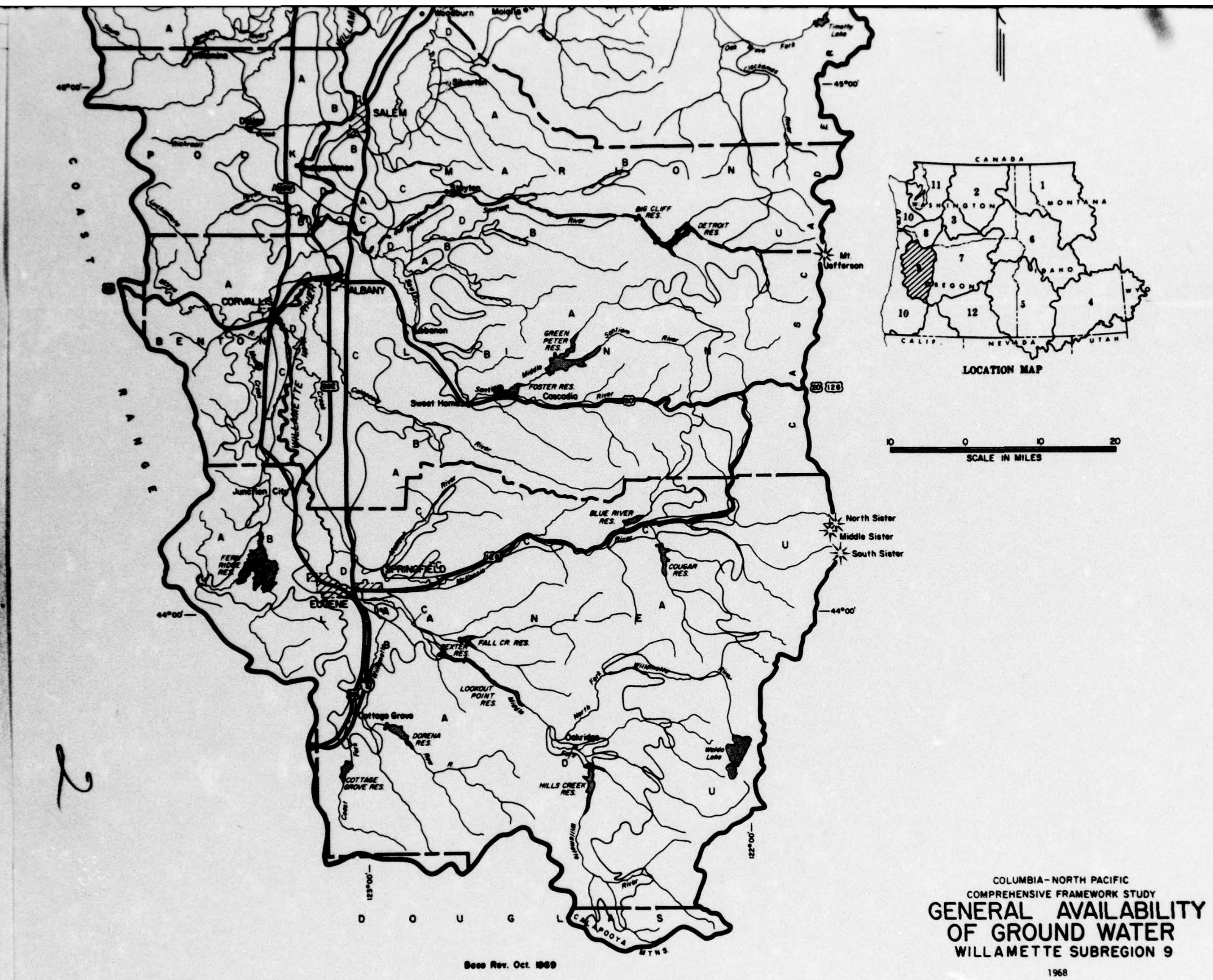
AQUIFER UNITS

WILLAMETTE SUBREGION 9

1968

FIGURE 661


EXPLANATION
Quantity generally available per well
A
1 to 20 gallons per minute
B
20 to 100 gallons per minute
C
100 to 500 gallons per minute
D
500 to 2000 gallons per minute
E
More than 2000 gallons per minute
U
Yield unknown; See aquifer unit map for information on possible yields
WASHINGTON
OREGON
COLUMBIA
WASHINGTON
MULTNOMAH
YAMHILL
CLACKAMAS
POLK
MARION
BENTON
LINN
COAST
COLUMBIA RIVER
BONNEVILLE DAM
St. Helens
PORTLAND
Hillsboro
Forest Grove
Oregon City
Sandy
Mt. Hood
Government Camp
BULL RUN RES.
NORTH FORK RES.
Timothy Lake
Mc Minnville
Woodburn
Molalla
Silverton
SALEM
Dallas
Independence
Stayton
BIG CLIFF RES
DETROIT RES.
Mt. Jefferson
ALBANY
CORVALLIS
Lebanon
GREEN PETER RES.
FOSTER RES.
Cascadia
Sweet Home
WILLAMETTE
123°00'
122°00'
45°00'
LOCATION MAP
CANADA
WASHINGTON
MONTANA
IDAHO
OREGON
CALIF.
NEVADA
UTAH
WYO



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER

WILLAMETTE SUBREGION 9

1968

FIGURE 662

2

According to table 361, as shown below, about 27 million acre-feet of water is stored in the uppermost 50 feet of the saturated zone in Subregion 9, of which about 65 percent is in the alluvial deposits in the Willamette and tributary valleys. The younger volcanic rocks and the Sardine Formation also contain large quantities of water.

Natural Recharge and Discharge

Recharge of aquifers in Subregion 9 is almost everywhere from direct precipitation and snowmelt. Average annual precipitation ranges from about 40 inches in the center of the Willamette Valley to more than 100 inches in some parts of the Cascade and Coast Ranges. Precipitation exceeds potential evapotranspiration except in the late spring and summer. Recharge occurs during the later part of the fall, in the winter, and in the spring.

The Coast Range is underlain almost entirely by aquifer units (Tov, Tm, Tcr), with low specific yields and permeabilities that quickly fill to the point where they discharge into even the most minor water course. Generally, the aquifers fill to the point that they reject potential recharge in late winter and spring.

At many places in the uplands and hills east of the Willamette Valley, the water table is in the weathered zone of the volcanic rocks (Tsf, Tcr, Tlbv). Recharge becomes significant in the fall and generally the water table reaches its highest position by midwinter, remaining at relatively high levels until late spring. At many places permeable horizons occur at depths of one to several hundred feet and in deeply dissected areas, discharge outlets for these aquifers may be at altitudes much below the upland surface. Commonly, water levels are at progressively lower levels in successively deeper aquifers beneath the upland. Recharge to the lower aquifers is by downward movement or leakage from surficial aquifers. Because of the storing and delaying effect of the overlying aquifers, recharge is continuous, and fluctuations of the water table in these deeper aquifers are much subdued. At a few places the shallow water table is truly perched but at most places there probably is no unsaturated material between the uppermost zone of saturation and the deep aquifers; there probably is a continuous hydraulic gradient between the shallow water table and the deeper aquifers.

The High Cascade Range is underlain by the younger volcanic rocks (QTv) which have a moderate specific yield and high permeability. Under these conditions, the water table is far below land surface at many places, and the regional water table is near the surface only where major valleys cut through the base of the deposits. However, at some places, shallow aquifers are perched on layers of fine-grained volcanic ash, and these may show considerable seasonal fluctuation.

The alluvial-aquifer unit (QTal) mostly underlies nearly flat terraces, benches, and plains where runoff is slow. The unit has high porosity and precipitation is absorbed readily. Hydrographs indicate that recharge from precipitation generally begins in late fall and continues until May or June. Peak levels usually are reached by early or midwinter. Continued rainfall after that time merely serves to hold the aquifer at near-capacity levels.

Discharge of ground water is continuous, but the quantity discnarged varies greatly, especially from areas underlain by aquifer units with moderately low to low specific yields (Tov, Tm, Tlbv, Tcr, Tsf) in which most of the ground-water storage is shallow. Discharge from those units declines rapidly during periods of no recharge. In contrast, discharge from the alluvial deposits and the younger volcanic rocks declines slowly.

Rough estimates of average annual recharge and discharge of ground water are given in table 361. These estimates are based on analyses of hydrographs of wells, and on the ground-water component of discharge of streams draining the various aquifer units. Average annual recharge to and discharge from aquifer units in the subregion is estimated to be about 11 million acre-feet. About one-half of the total is from the younger volcanic rocks in the High Cascade Range and about one-fourth from the alluvial deposits in the Willamette and tributary valleys. Hydrographs of representative wells are shown in figure 663.

Annual Ground-Water Withdrawal

Annual ground-water withdrawal, table 362, based on 1965 to 1967 data and projected to 1970, is estimated to be about 320,000 acre-feet. Nearly half of that amount is withdrawn for irrigation of about 90,000 acres.

Chemical Quality of Water

Ground water in the subregion ranges generally from soft to moderately hard. Fluoride and boron concentrations, and the sodium adsorption ratio, generally are low. Iron is in excess of recommended limits in some wells.

Water from most aquifer units has dissolved-solids concentrations of less than 500 mg/l. However, water from marine strata (Tm) at depths of a few hundred feet may be moderately to highly saline, and at a few places, saline water has been encountered at depths of less than 100 feet. Saline water also is found at a few places in the older volcanic rocks (Tov), in the Little Butte Volcanic Series (Tlbv), or in the Columbia River Group (Tcr). This

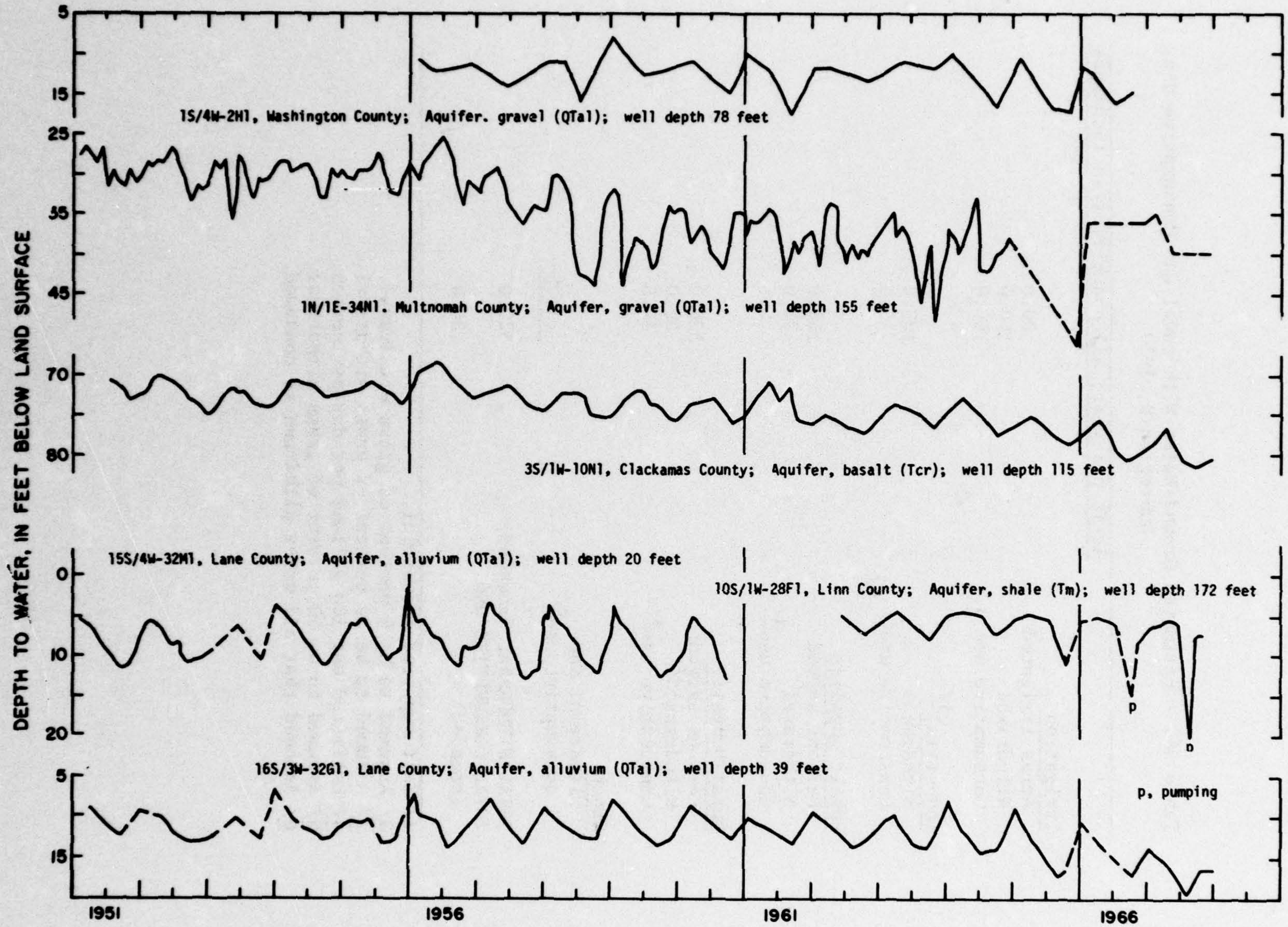


Figure 663 Hydrographs of selected wells in subregion 9

Table 362 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 9, 1970

	Ac-ft per year; all quantities in thousands
Irrigation	
Acres irrigated	90.0
Withdrawal	150.0
Consumptive use	100.0
Industrial 1/	
Withdrawal	100.0
Consumptive use 2/	5.0
Public Supplies	
Persons served	165.0
Withdrawal	28.0
Consumptive use 3/	5.6
Rural-Domestic	
Persons served	350.0
Withdrawal 4/	39.0
Consumptive use 5/	19.5
Stock	
Withdrawal and consumptive use 6/	1.75
TOTAL WITHDRAWAL (rounded)	320.0
TOTAL CONSUMPTIVE USE (rounded)	130.0

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

saline water is believed to be water that has migrated into these units from underlying or interfingering marine sedimentary strata. The saline water may have high fluoride content and sodium adsorption ratio.

Arsenic, in concentrations slightly to considerably in excess of the recommended limits for drinking water, was found in water from some wells in an area extending southward from Eugene through Creswell and Cottage Grove. (38) The water apparently is from the Fisher Formation which is included with the older volcanic rocks (Tov) on the aquifer-unit map, figure 661. The Fisher Formation underlies the Little Butte Volcanic Series and the alluvial deposits at places in the area.

Present Use and Future Availability

The alluvial deposits (QTal) that underlie the Willamette Valley supply most of the ground water utilized in Subregion 9. Moderately large to large yields of good-quality water are obtained at many places, but some fairly extensive areas of predominantly fine-grained sediments yield only small to moderate supplies. Basalt of the Columbia River Group (Tcr) is an important aquifer in the northern Willamette Valley where it yields moderate to moderately large supplies at some places. The younger volcanic rocks (QTv) also yield moderate to moderately large supplies locally. Other aquifer units usually yield only small to moderate quantities of water but are utilized extensively for domestic use.

Estimates of ground-water withdrawal and the quantity used consumptively are given in table 362. Total annual withdrawal was estimated to be about 320,000 acre-feet, and consumptive use about 130,000 acre-feet. Because some of the ground-water withdrawn returns to streams, net withdrawal exceeds consumptive use, and may be approximately 200,000 acre-feet a year.

Most of the withdrawal is from the alluvial deposits; a relatively small part is from the Columbia River Group, the younger volcanic rocks, the Little Butte Volcanic Series, and the Sardine Formation in areas within or adjacent to the Willamette Valley. Estimated natural recharge to and discharge from these units in the area of withdrawal is on the order of 3 million acre-feet; net pumped withdrawal is about 7 percent of this amount, or 210,000 acre-feet.

It is obvious that large additional supplies of ground water are available for development in the Willamette Valley, chiefly from the alluvial deposits. Not only is present withdrawal just a small fraction of present natural recharge, but present natural recharge would be increased by increased withdrawals. Storage depleted

during the dry summer months would be replenished largely during winter and spring and some potential recharge formerly rejected would become actual recharge. (128A)

The ground-water availability map shows the general range in yield of wells in various areas. However, even in areas shown as having only moderate yields, larger supplies could be obtained by using groups of wells. Also, better drilling methods and development techniques would result in larger yields.

A large quantity of ground water is stored in the younger volcanic rocks in the High Cascade Range, and these rocks probably will yield large quantities of water to wells. There seems to be little possibility that this supply will be needed within the mountains in the near future, and it probably will remain for some years as an untapped reserve for future requirements.

Although only small to moderate yields can be obtained from individual wells in the other volcanic rocks (Tsf, Tcr, Tlbv, Tov) of the hills and mountains, the aggregate available supply is large. Generally there is little interference between wells, and frequent recharge refills the aquifers. Recharge to deep aquifers within these units may, however, be more restricted and large local drawdowns can occur. The Cooper Mountain-Bull Mountain-Tigard area is one in which water levels in the basalt (Tcr) have shown a serious progressive decline because of excessive withdrawal in relation to the restricted recharge through the overlying deep soil and subsoil.

Artificial Recharge

Information on artificial recharging as of 1962 is given in a report by Price, Hart, and Foxworthy (125) which is summarized in the following paragraphs.

The supply for the city of Springfield is obtained from shallow alluvial deposits near the Willamette River. During the summer months when the water table and river level are low, the well yields decrease considerably. The water table is raised and yields increased by adding river water to the aquifer through injection wells.

An industrial plant in northeast Portland returns well water used in processing to the aquifer through an injection well. Precipitation on about 12 acres also drains into the well.

Several commercial buildings in Portland return well water used in heat-exchange processes to the ground through injection wells. At most installations the disposal well is a few hundred feet deep in gravel of the Troutdale Formation (QTal) and the supply well is in basalt of the Columbia River Group (Tcr) several hundred feet deeper.

Generally, the alluvial deposits can readily be recharged either by water spreading, or through relatively shallow injection wells. However, because in most areas much potential recharge is rejected each spring, there is no general need for recharging at the present time. Recharging may be desirable locally where the permeable deposits are shallow and thin, as at Springfield, and the decline of the water table reduces yields during summer droughts. At some places natural recharge to deeper alluvial deposits or volcanic-rock aquifers is restricted because of overlying materials of low permeability. Local recharge of these aquifers through injection wells is feasible, and may be desirable.

Water Rights

In Subregion 9, consisting essentially of the Willamette and Sandy Basins, primary water rights for 5,400 wells were on file with the State Engineer's Office as of March 1967. Prime rights allow withdrawal of 707,949 acre-feet a year, of which 365,320 acre-feet are for irrigation of 146,056 acres. The maximum rate of withdrawal is 2,207 cfs (990,000 gpm), during the irrigation season. Data on supplemental-water rights are not available. Ground-water rights are summarized by major-use category, in table 363, as shown below.

Table 363 - Summary of Ground-Water Rights, Subregion 9, 1967

Basin No.	Basin Name	Number of Wells	Domestic (ac-ft)	Municipal (ac-ft)	Industrial (ac-ft)	Irrigation (acres)	Irrigation (ac-ft)	Other (ac-ft)	Total (ac-ft)
2	Willamette	5,375	195	191,350	140,330	145,530	364,000	6,980	702,855
3	Sandy	25	7	2,100	1,450	526	1,320	217	5,094
	TOTAL	5,400	202	193,450	141,780	146,056	365,320	7,197	707,949

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

Ground water is effluent to streams throughout the year nearly everywhere in Subregion 9. The few exceptions include three general situations:

1. Local areas adjacent to a stream where the water table is drawn down below river level by pumping from wells, such as on the west side of the Willamette River, at Portland. (9-19 and pl. 2) The natural gradient from aquifer to river is reversed in these situations and water from the river recharges the aquifer. (figure 663)

2. Short reaches where streams entering lowlands and valleys lose some water to alluvial deposits at the margins of the lowlands. Generally, the water returns to the same stream, or an adjacent stream, in a short distance.

3. Some streams in the High Cascade Range flow alternately across materials of low and high permeability. Where these streams cross highly permeable materials that crop out downvalley at lower elevations, they may lose all or part of their flow, the water re-entering the streams downvalley.

In the Willamette Valley and the broader valleys tributary to it, the water table generally has low gradient toward the stream. During prolonged dry periods, heavy withdrawals from aquifers near the stream may cause temporary reversals of the gradient, and induce recharge from the stream.

The ratio of ground-water effluent to direct surface runoff varies greatly from time to time, and the average ratio differs greatly between aquifer units. The ground-water component of flow for streams draining the younger volcanic rocks (QTv) in the High Cascade Range ranges from 75 to 90 percent of the average annual flow. Generally, the entire discharge is ground-water effluent for most of the year and direct surface runoff occurs only during and immediately following storms. The rate of recession of base flow in these streams is relatively low; the discharge of the North Santiam River near Detroit requires 120 days to decline from 1,000 to about 350 cfs.

The marine sedimentary rocks of Tertiary age (Tm) and older volcanic rocks (Tov) apparently yield the lowest component of ground-water effluent to streams of any aquifer unit. Although ground-water discharge is fairly large when those aquifers are full, discharge declines very rapidly during periods of no recharge as ground-water storage is depleted. The ground-water component of the average flow of streams draining these aquifers is on the order of 10 percent.

The ground-water components of flow for streams draining other aquifer units (Tsf, Tlbv, Tcr) range generally from 20 to 35 percent of average annual discharge. During periods of no recharge, discharge declines much more rapidly than it does for the younger volcanic rocks (QTv) but less sharply than from the older volcanic rocks (Tov) and the marine sedimentary rocks (Tm). Low-flow characteristics of selected streams are shown in figure 664.

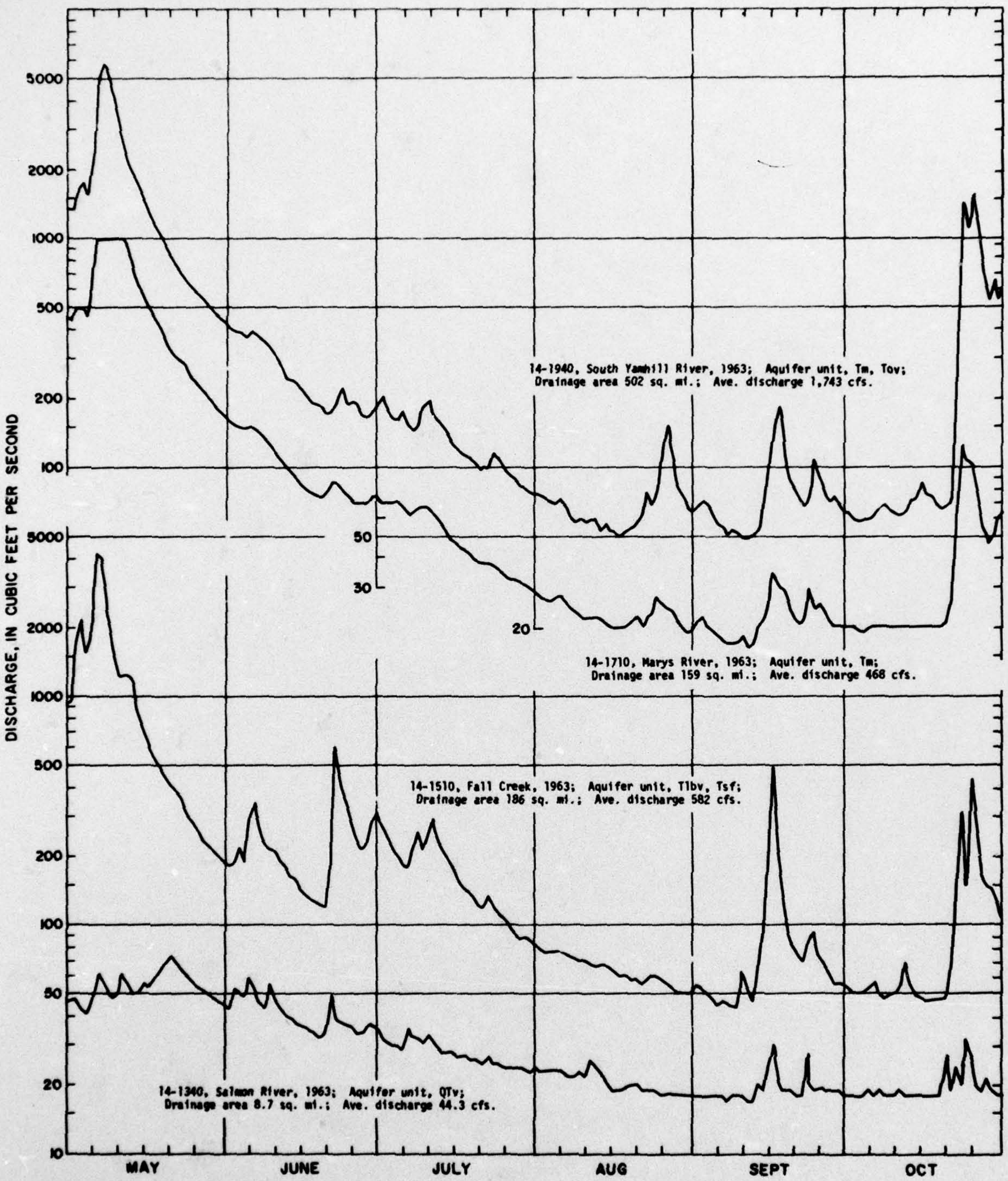


Figure 664 Hydrographs showing low-flow characteristics of selected streams

S U B R E G I O N   10,   C O A S T A L

HYDROLOGIC FRAMEWORK

The Coastal Subregion comprises the entire coastal areas of the States of Washington and Oregon as shown on figure 374. It extends from the Canadian border on the north to the California border on the south and from the Pacific Ocean on the west to the summit of the Coast Range on the east. In southern Oregon the Coast Range expands eastward to the Cascade Range and that entire area is drained from east to west by the Umpqua and Rogue Rivers. The Olympic Mountains fill the northern portion of the subregion, with foothill ridges 4,500 feet to 5,000 feet in elevation and sharp ridges and crags extending to 7,000 and 8,000 feet. The Coast Range, generally below 2,500 feet, extends from the Chehalis River to the Umpqua River. The mountainous Rogue River Basin has numerous peaks over 5,000 feet in elevation. The subregion area is 23,763 square miles, of which 241 square miles are water and 23,522 square miles are land, altogether amounting to about 9 percent of the total area of the region.

Figure 2 shows the general physiographic features of the subregion. Only a small percentage is valley floor and most of this is in the Chehalis and Rogue River Basins and the tidal areas of all streams. The rocks in the Coast Range are a series of sediments, both marine and continental, with some volcanics; and the rocks in the Rogue Basin are metamorphosed ancient sediments and related intrusions, but are overlain in the east by the recent sediments and lavas of the Western Cascades.

Streams in this subregion averaged about 43 inches of runoff per year or 87,615 cfs during the period 1929-58. The maximum was about 1 2/3 and the minimum about 1/2 of the average. Runoff varies from heavy in the north to moderate and more variable in the south.

Stream gradients range from about 1 to 8 percent in the upper reaches (with some up to 14 percent) but are less than 1/4 percent in the lower valleys. The higher gradients are on the Hoh and Quinault Rivers in the Olympic Mountains and on the Rogue River in the Siskiyou Mountains. The lowest gradients are on the Chehalis River. The principal streams are the Chehalis in Washington and the Nehalem, Umpqua, Coquille, and Rogue in Oregon, but only the Umpqua and Rogue Rivers drain considerably more than 1,000 square miles. The Hoh and Quinault River Basins in Washington contribute

the heaviest runoff at about 125 inches per year; the lowest contributor in that state is the Chehalis with only about 55 inches. Heavy contributors in Oregon are the Wilson and Siletz River Basins with about 100 inches per year each. Southward the runoff decreases to about 35 inches per year for the Umpqua and Coquille River Basins and 30 inches for the Rogue. Rainfall during winter is the source of runoff, with secondary supply in the spring from snowmelt in the Olympic Mountains and in the upper Umpqua and Rogue Basins.

Many small alpine glaciers and perennial snowfields contribute minor amounts of runoff to streams in the Olympic Mountains. Glacier contribution is negligible in the Umpqua and Rogue River Basins.

Most of the subregion contains the soils derived from the sedimentary rocks of the Coast Range. However, the upper Rogue River area is blanketed by pumice and underlying porous lava.

The native land cover is nearly all dense conifer forest. The primary species of tree is Douglas-fir, changing to pine in the Umpqua and Rogue Basins. Considerable areas are covered with hemlock, cedar, spruce, alder, oak, maple, and brush.

The cities of Medford, Aberdeen, Roseburg, and Astoria are the largest in the subregion with populations as of 1960 as follows, respectively: 24,425, 18,471, 11,467, and 11,239.

CLIMATE

The inland valleys of the Umpqua and Rogue Rivers have a significantly different climate from that of the remaining coastal area. Accordingly, the discussion on climate has been separated for these two areas.

West of the Coast Range

Precipitation

The Pacific Ocean borders the full length of this subregion on the west giving it a very definite marine climate. The general movement of practically all large air masses crossing this area is from west to east. Prior to arrival at the coast, the air masses have spent several days' travel over the Pacific Ocean. In that time they have become nearly saturated and their temperatures closely approach that of the ocean. In the immediate coastal area, year-round temperature ranges are relatively small. There is considerable rain during the late fall, winter, and early spring

and the usual amount of fog and low clouds associated with a marine climate. During the winter, ocean-spawned storms frequently move across the subregion. At this time the ground is much cooler than incoming air from the ocean. Immediately after crossing the coastline this saturated air is subjected to two cooling processes--by contact with the much colder land surface over which it is passing, and by lifting in its forced ascent across the Coast Range. This latter process reduces the temperature at a rate of from 3 to 5°F. for each 1,000-foot increase in elevation. This cooling condenses a great deal of moisture on the west slopes of the Coast Range to add to the already very substantial storm totals. These combine to make this one of the heaviest rainfall areas in the contiguous United States. Annual averages on the higher slopes range from 150 to 200 inches. Along the coast, annual averages of 75-85 inches are common. Table 374 and figure 665 give precipitation data and location of precipitation stations. Two of the listed stations, Cushman Dam and Falls City, are outside the subregion hydrologic boundary.

Table 374 - Average Monthly and Annual Precipitation, Coastal Subregion, 1931-60

Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Tatoosh Is. WB	101	10.82	8.70	8.34	5.23	3.00	2.84	2.34	1.98	3.55	8.22	10.51	12.16	77.69
Forks 1 E	350	17.49	14.12	12.69	8.33	4.89	3.69	2.50	2.25	5.11	11.70	15.08	19.25	117.10
Aberdeen	12	12.70	10.23	9.19	5.56	3.43	2.70	1.51	1.79	3.71	8.13	11.09	14.50	84.54
Willapa Harbor	150	12.37	10.43	9.89	5.94	3.68	3.17	1.46	1.73	3.55	8.50	11.25	14.59	86.56
Astoria1/	200	11.91	9.31	8.61	5.28	3.56	2.98	1.20	1.32	3.36	6.30	10.98	12.62	77.43
Vernonia1/	744	7.53	6.36	5.04	3.04	2.12	1.52	.46	.80	1.69	4.46	7.02	7.53	47.57
Newport	136	10.01	8.38	8.38	4.16	2.93	2.39	.81	.92	2.31	6.12	8.80	11.02	66.23
North Bend FAA AP	11	10.29	8.35	7.63	3.87	2.77	1.69	.43	.52	1.73	5.49	8.56	10.49	61.82
Roseburg WB AP	505	5.51	4.21	3.42	1.93	1.85	1.50	.21	.31	1.00	3.02	4.46	5.69	33.11
Prospect 2 SW	2,482	6.60	4.94	4.55	2.90	2.73	1.80	.33	.30	1.06	3.95	5.67	6.86	41.69
Medford WB AP	1,312	3.14	2.40	1.78	1.06	1.47	1.02	.21	.18	.60	1.94	2.60	3.38	19.78
Ashland 1 N	1,780	2.78	2.15	2.06	1.30	1.74	1.20	.34	.27	.78	1.84	2.53	3.00	19.99
Brookings	162	13.16	11.07	10.19	5.42	4.30	2.46	.58	.58	1.84	7.27	10.75	13.78	81.40

1/ Period is longer or shorter than the 30-year normal.

Immediately adjacent to the coast, snow is of little significance. The annual average is about 1-2 inches with many years having no measurable amount. Moving inland this gradually increases, as it also does in moving from south to north. This *increase is sharply accentuated by increases in elevation.* A few miles inland annual total snowfalls may range from 5 to 20 inches, and on the upper slopes of the Olympic Mountains the usual seasonal fall is between 300 and 500 inches. On these higher slopes the first measurable snow generally occurs by early October, and a continuous cover will persist from early November to late June, with year-round glacial ice in some areas of the Olympic Mountains. While there is usually a fairly substantial amount of snowfall each year in elevations between 500 and 1,500 feet, it almost always melts within a few days under rising temperatures and the change to rain. Density of the mountain snowpack increases from about 25 percent water equivalent in early winter to about 45 percent in April.

Figure 665 is an isohyetal map prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors.

Temperature

There is only about a 15-20 degree difference between the mean January and July temperatures in any of the coastal area, with a tendency for this difference to increase slightly with increase in distance from the ocean. Extreme temperatures are very rare. On the average there are not more than 1-2 days a year with temperatures of 90°F. or higher in the immediate coastal area, and those of 0°F. or lower are practically unknown. Moving inland a few miles, the number of days with 90°F. and above may increase to as many as five a year but those below 0°F. are extremely rare, except for the higher slopes of the Olympics. Days with minimums of 32°F. or less, however, have a long-period average of from about eight a year in southern Oregon to as many as 40 in northern Washington. Table 375 and figure 665 give temperature data and the location of weather stations.

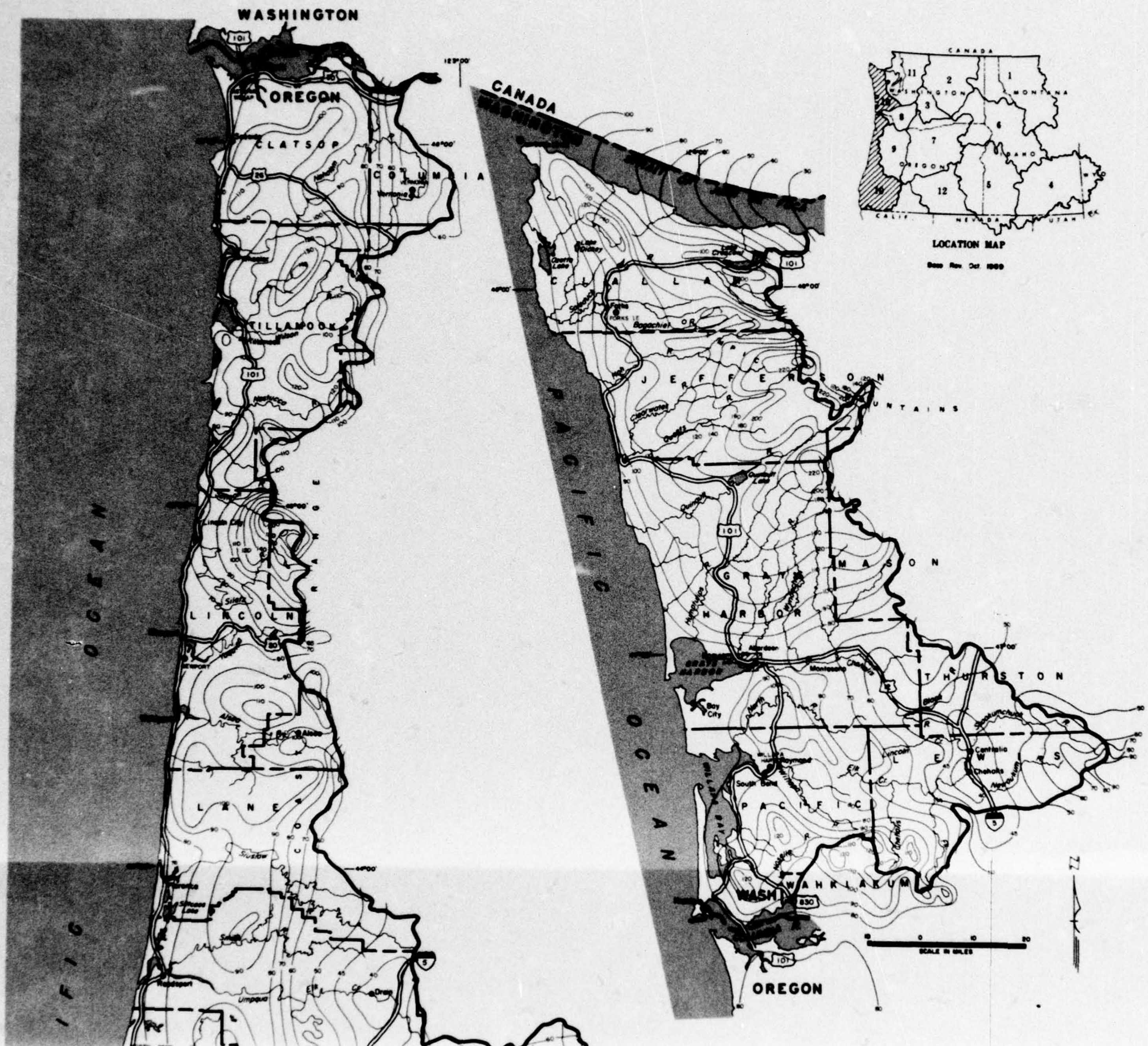
The growing season ranges from 189 days at Aberdeen in the north, to 251 days at Astoria, 284 days at Newport, and 300 days at Brookings in the south. The average dates of the last freeze are, respectively, April 19, March 18, March 1, and February 20. The average dates of the first freeze in the fall are, respectively, October 25, November 24, December 10, and December 17.

Wind

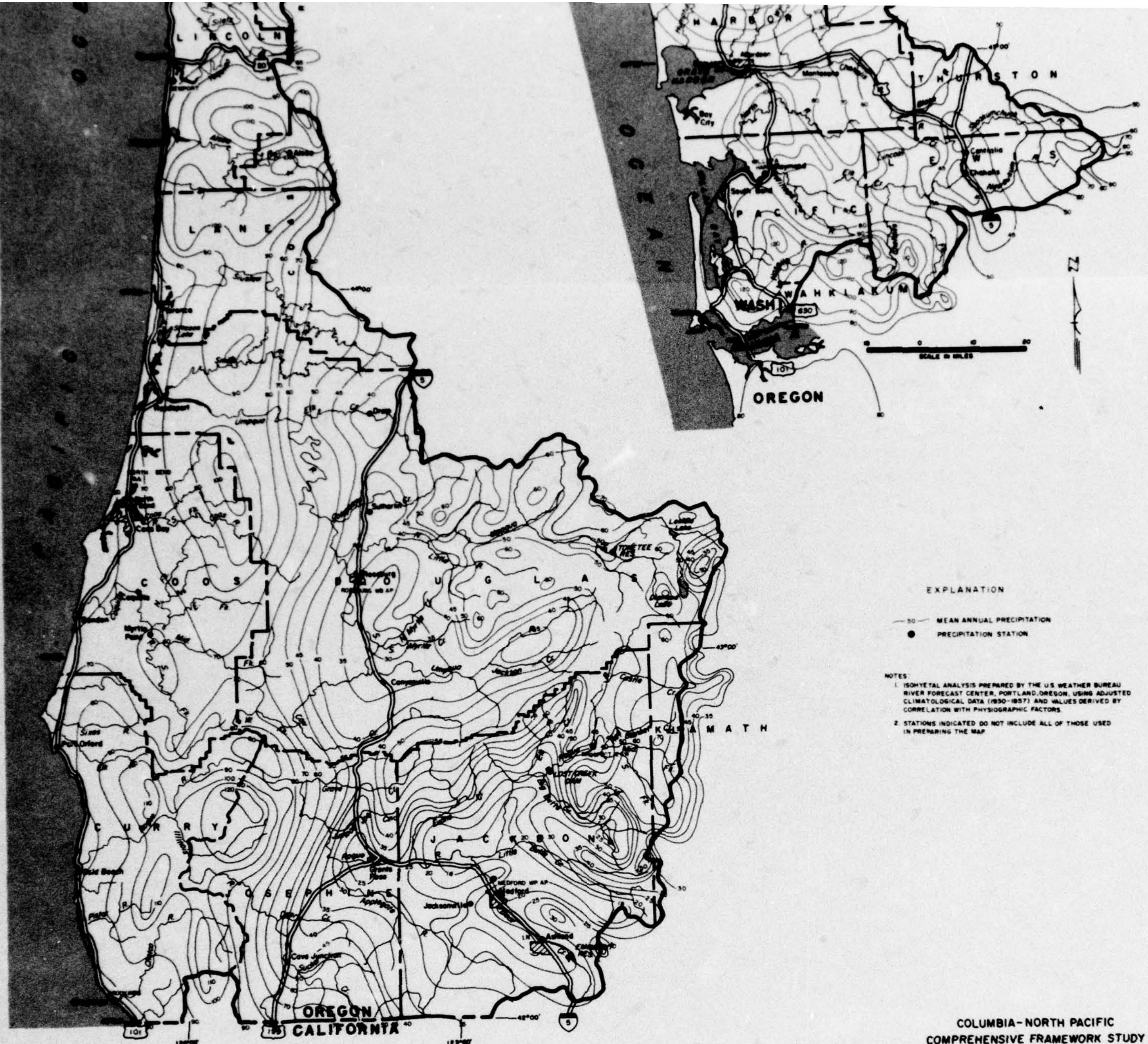
This area, more than any other in the region, is exposed directly to the major winter storms that frequently move on to the Oregon-Washington coast, often with quite violent winds. Only a limited amount of recorded wind information is available for the area; but, based on these data, it seems reasonable to assume that winds with speeds up to 60-70 mph occur almost every winter and those exceeding 100 mph have been recorded on at least four or five occasions in the last 65 years. The prevailing direction on an annual basis is generally westerly, with the southerly or southwesterly component greatest in winter and the northwesterly component predominating in summer.

Evaporation

Despite relatively cool temperatures and fairly high humidity, there is an average April through October total evaporation of



WASHINGTON
OREGON
CLATSOP
COLUMBIA
TILLAMOOK
LINCOLN
LANE
OCEAN
PACIFIC
CANADA
WASHINGTON
CLALLAM
JEFFERSON
MOUNTAINS
GRAYS HARBOR
MASON
THURSTON
LEWIS
PACIFIC
WAHKIAKUM
PACIFIC OCEAN
OREGON
SCALE IN MILES
LOCATION MAP
CANADA
WASHINGTON
MONTANA
OREGON
IDAHO
NEVADA
UTAH
CALIF.



EXPLANATION

—50— MEAN ANNUAL PRECIPITATION

● PRECIPITATION STATION

NOTES:

1. ISOHYETAL ANALYSIS PREPARED BY THE U.S. WEATHER BUREAU RIVER FORECAST CENTER, PORTLAND, OREGON, USING ADJUSTED CLIMATOLOGICAL DATA (1930-1957) AND VALUES DERIVED BY CORRELATION WITH PHYSIOGRAPHIC FACTORS.
2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

COASTAL SUBREGION 10

1968

FIGURE 665

6

Table 375. Average and Extreme Temperatures (°F), Coastal Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Tatoosh Is.WB	Av. Max.	44.7	46.0	47.8	51.1	54.5	57.4	59.3	59.6	58.5	55.1	50.3	47.6	52.7
(71)	Av. Min.	38.4	39.1	40.2	42.9	46.4	49.6	51.4	51.5	50.0	47.6	43.5	41.2	45.2
	Mean	42.0	43.1	44.2	47.5	51.1	53.9	55.5	56.0	54.8	51.9	47.2	44.4	49.3
	Highest	64	64	69	75	81	84	88	80	80	77	68	61	88
	Lowest	7	13	24	33	35	43	44	43	40	33	19	19	7
Forks 1 E	Av. Max.	44.0	47.3	50.7	56.3	62.8	66.2	70.8	71.7	68.2	60.3	51.0	45.9	57.9
(45)	Av. Min.	32.3	33.5	35.0	37.4	41.7	46.1	48.6	48.8	46.4	42.5	37.0	34.4	40.3
	Mean	38.7	40.3	42.5	46.9	52.1	56.0	59.7	60.0	57.6	51.5	44.1	40.6	49.2
	Highest	67	67	79	85	91	98	101	98	96	87	69	64	101
	Lowest	3	8	12	21	25	33	35	34	24	21	10	-4	-4
Aberdeen	Av. Max.	45.3	49.0	52.2	58.0	63.1	66.4	69.7	70.1	69.0	61.9	52.4	47.5	58.7
(27)	Av. Min.	34.0	34.6	35.9	39.5	43.6	47.9	50.5	51.0	48.3	43.5	38.0	36.3	41.9
	Mean	39.7	41.8	44.1	48.7	53.3	57.1	60.1	60.6	58.7	52.7	45.2	41.9	50.3
	Highest	66	70	79	84	92	101	104	97	97	85	70	62	104
	Lowest	6	8	21	25	29	34	37	39	33	19	11	16	6
Vernonia 1/	Av. Max.	43.8	48.4	52.8	60.0	66.6	69.8	77.1	76.5	74.0	62.8	51.8	46.4	60.8
(20)	Av. Min.	28.8	31.1	32.0	35.3	39.7	43.9	46.4	46.3	43.8	38.7	33.7	31.8	37.6
	Mean	36.3	39.8	42.4	47.6	53.2	56.8	61.8	61.5	58.9	50.8	42.8	39.1	49.3
	Highest	62	65	81	87	95	96	106	102	100	89	74	62	106
	Lowest	-8	0	9	21	25	30	34	32	26	21	12	10	-8
Falls City	Av. Max.	44.4	49.4	54.0	61.2	67.1	72.3	80.5	80.4	74.3	63.5	52.5	46.5	62.2
(49)	Av. Min.	31.2	33.4	35.3	38.0	41.8	45.7	47.8	47.8	46.2	42.0	36.5	33.5	39.9
	Mean	37.9	41.1	44.4	49.5	54.8	59.2	64.4	64.5	61.4	53.4	44.3	40.5	51.3
	Highest	68	67	82	88	92	102	106	102	100	90	74	63	106
	Lowest	-5	1	18	23	26	32	36	36	26	23	10	-2	-5
Newport	Av. Max.	49.6	51.3	52.8	56.0	58.9	61.9	63.9	64.4	64.0	60.7	55.3	51.0	57.5
(64)	Av. Min.	37.7	44.7	39.1	41.5	44.7	48.2	50.0	50.5	48.7	46.2	42.5	39.6	44.5
	Mean	43.7	44.9	46.0	49.2	52.3	55.8	57.4	57.7	56.8	53.6	48.8	45.5	51.0
	Highest	77	74	83	88	94	100	97	97	95	90	76	73	100
	Lowest	1	12	22	29	30	33	39	38	33	27	19	11	1
RoseburgWBAP	Av. Max.	47.3	51.8	57.1	63.1	69.0	74.6	82.4	82.2	76.0	65.0	53.9	48.0	64.2
(83)	Av. Min.	34.9	36.1	37.9	40.7	45.0	49.6	53.2	52.7	49.1	43.7	39.2	36.4	43.2
	Mean	40.3	43.3	46.6	51.5	56.5	61.5	67.9	67.6	62.8	54.4	46.1	42.0	53.4
	Highest	71	79	85	96	102	106	109	106	104	96	76	70	109
	Lowest	-6	3	18	25	26	34	40	39	29	22	14	5	-6
Medford WBAP	Av. Max.	44.8	52.2	58.3	66.1	72.7	79.3	89.3	88.5	82.5	69.0	55.6	45.6	67.0
(31)	Av. Min.	29.9	32.5	34.8	39.0	44.2	49.8	55.1	53.5	47.7	40.4	34.8	32.1	41.2
	Mean	35.4	40.1	44.3	50.6	57.5	64.2	72.0	70.7	64.2	53.0	42.4	36.9	52.6
	Highest	68	74	86	92	100	105	115	108	107	97	75	65	115
	Lowest	-3	6	16	21	28	31	40	41	29	20	15	3	-3
Brookings	Av. Max.	53.4	55.1	56.4	58.9	62.2	65.7	66.7	66.7	67.8	63.8	58.6	54.6	60.8
(45)	Av. Min.	40.0	40.5	41.2	43.1	45.5	48.4	50.2	50.7	50.1	47.5	44.1	41.2	45.2
	Mean	47.1	48.0	48.9	51.1	54.6	57.7	58.9	58.9	59.5	56.0	51.7	48.8	53.4
	Highest	78	80	88	92	99	100	99	98	100	96	88	79	100
	Lowest	21	26	29	30	33	34	41	37	34	32	28	17	17

1/ Period is longer or shorter than the 30-year normal.

Note: The mean temperature is for the normal period 1931-60; other data are for the period of record through 1960. Numbers under station names denote full years of record for all data.

20-25 inches as measured in Class A evaporation pans. The evapotranspiration averages as computed by the Palmer-Havens application to the Thornthwaite method is for a potential evapotranspiration of 25 inches annually; the computed actual value for soils with a 2-inch water holding capacity is 18-20 inches, and for those of a 6-inch water holding capacity it is 20-24 inches.

Storms

Nearly all of the widespread winter precipitation in the area is produced either by a family of mature occlusions or by a quasi-stationary front with active minor waves. These storms may extend many hundreds of miles to the north or south and are generally 3 to 5 days in duration. Tropical cyclones are extremely rare and summer thunderstorms are of local rather than general occurrence. The infrequent hail or sleet storms over the area seldom reach destructive proportions.

Humidity

The abundance of fresh marine air continually moving into the coastal area, together with the small daily temperature ranges, result in very little seasonal or diurnal range in relative humidity. There is only about 20 percent difference between the long-period average of near 90 percent in the early morning, when it is highest, and about 70 percent in the warmest part of the day, when the relative humidity tends to be lowest.

Sunshine

The average daily cloudiness west of the Coast Range varies from about 60-65 percent of the sky covered in August and September to 80-85 percent covered in December and January. The long-term average for sunshine is from about 25 percent of the time possible in winter to near 50 percent of the time possible in summer. Fog occurs often, particularly during the winter months.

Umpqua and Rogue Valleys

Precipitation

By the time the incoming marine air has reached the inland valleys of the Umpqua and Rogue Rivers, it has been greatly modified by its passage over a relatively high section--mostly 3,500 feet and higher--of the Coast Range. In being lifted over those mountains a

considerable amount of moisture is condensed and precipitated on their west slopes. Contact of the incoming air with land surfaces, which heat much more rapidly than the ocean in summer and cool more rapidly in winter, produces very different seasonal temperature patterns.

These valleys are slightly south of the main path for winter storms and this, combined with the drying out of air masses crossing the Coast Range, results in rainfall which is only a fraction of that experienced in the coastal portions of Subregion 10. Totals range from 20 to 35 inches on valley floors and gradually increase to nearly 100 inches at the crest of the Coast Range. The pattern of occurrence, however, is similar to most of Oregon with most of rain falling during the winter months.

The average annual snowfall in the lower elevations ranges from 10 to 25 inches a year and increases fairly rapidly with increases in elevation. At Crater Lake this average is 575 inches, with nearly 900 inches having occurred in some years.

Temperature

Average monthly mean temperatures on the valley floors range from 35-40°F. in January to 70°F. in July. The average January daily minimums are generally from 28° to 32°F. and July average daily maximums 85-90°F. Temperatures as high as 115°F. and as low as 12°F. below zero have been officially observed; but for most years, at the lower elevations, the annual extremes will not be higher than 105°F. or lower than 15°F. In the lower valley areas there is an average of 20-40 days a year with maximums of 90°F. or higher and 90-110 days with minimums of 32°F. or lower. In moving up the slopes of surrounding mountains both maximums and minimums decrease with increase in elevations. At the Crater Lake National Park headquarters, with an elevation of nearly 6,500 feet making it the highest weahter station in this subregion, there are an average of 234 days a year with minimums below 32°F. and less than 1 day a year with maximum above 90°F.

Wind

This area has most of its high winds out of the south-to-west quadrant since this is the direction from which most major storms move. The prevailing wind, however, fairly closely follows the direction of the valley at the point where it is being recorded. Maximum velocities over the valley floor rarely exceed 50 miles per hour, but often exceed this at elevations of 5,000 to 10,000 feet.

Evaporation

The combination of relatively warm summers, low relative humidities and considerable sunshine results in a fairly high potential for evaporation and evapotranspiration. The annual average Class A pan evaporation recorded at the Medford Experiment Station is approximately 43.5 inches, 35 percent occurring during July and August. The computed potential evapotranspiration in lower elevation areas is 26.6 inches. The computed actual evapotranspiration for soils with a 2-inch water capacity is between 12 and 15 inches; for those with a 6-inch capacity it is 15-20 inches.

Storms

Storms in this area are similar to those in the remainder of the subregion. Total precipitation may exceed 10 inches at Gold Beach near the coast and at Crater Lake near the crest of the Cascade Range, but contribute only 3 or 4 inches on the valley floor near Medford. Convective-type storms with lightning and hail are common during late spring and early summer, but produce floods only in local areas along small streams.

Humidity

Relative humidity varies over wide seasonal ranges. In the early morning hours it is often 100 percent with a 4:00 a.m. November and December average at Medford of 94-95 percent. In contrast, the September 4:00 p.m. average is only 28 percent with frequent values well below 20 percent and occasionally less than 10 percent.

Sunshine

During the late fall and winter months there is considerable cloudiness, but through the spring, summer, and early fall there is an abundance of sunshine. The average daily cloudiness ranges from 85 percent of the sky covered in December to only about 20 percent in July and August.

Fog occurs in all months of the year, predominantly during the October-March period and particularly in the basin around Medford, but is generally confined to late night and early morning hours. Its distribution is irregular; it is least at elevations of several hundred feet above the valley floor.

SURFACE WATER

Except for the Rogue and Umpqua Basins and at the harbors, there has been relatively little development in the streams of Subregion 10, but the quantity of water is great and its quality is very good. The runoff is mostly from winter rainfall but considerable snowmelt is included in streams draining the Olympic Mountains and the Umpqua and Rogue River Basins. There is essentially no regulation for flood control, but four large flood-control reservoirs have been authorized for construction, the Wynoochee in Washington and Elk Creek, Applegate, and Lost Creek Reservoirs in the Rogue River Basin.

Water is used for power generation in the North Fork Umpqua River and in the Rogue River Basin.

Irrigation is important in the Rogue River Basin where there are a number of storage reservoirs, and the new reservoirs will provide more irrigation water.

Navigation is limited to the harbors, except for log rafting and pleasure boating. Harbor development has taken place and is continuing at the mouths of nearly all the coastal streams of Oregon and Washington and in the Columbia River.

Quantity

Average discharge of streams in the subregion totals about 87,615 cfs (63.5 million acre-feet annually). This averages 3.7 cfs per square mile, one of the highest rates in the Columbia-North Pacific Region, but reflecting the lower contribution from the southern portion of the subregion.

Present Utilization

About 1.1 percent of the mean discharge was withdrawn in 1965 for consumptive uses, but much less than 1 percent was actually consumed. About one-fifth of the water withdrawn for consumptive uses (about 990 cfs) was for municipal supplies (60 cfs domestic and 123 cfs industrial); the largest user was self-supplied industry (410 cfs). Irrigation was the second largest withdrawal, 363 cfs, but the major consumer, 219 cfs of the total of 293 cfs consumed. A very small amount of water was used for hydroelectric power generation. Recreation has always been popular along the coast, but with the mild climate and abundance of water, recreation is becoming a major industry. All waters are used to some degree for fish and wildlife.

Stream Management

Competition for water among the various users necessitates efficient stream management. Storage and release, diversions, conservation, legal constraints, etc., all are a part of the water-management system.

Impoundments Reservoirs having a total capacity of 5,000 acre-feet or more are listed in table 376. As footnoted in the table, Fourmile, Howard Prairie, and Hyatt Reservoirs are located outside the subregion; water stored in them is diverted across the divide for use within the subregion.

The primary use of the impoundments is for irrigation, and the water is supplied at a fairly constant rate from April through September. On the other hand, recreation use requires that the water be retained in the reservoirs as long as possible during the summer. Temperature regulation is very important for the Rogue River fishery and has been a major consideration in the design of the three large authorized reservoirs in the Rogue River Basin.

Diversions Most of the diversions in the Coastal Subregion are for irrigation. This is particularly true in the Rogue River Basin, because the deficiency in rainfall during the growing season makes a supplemental water supply necessary for successful crop and orchard production. The diversions are made for distribution of the water stored in the reservoirs listed in table 376.

Table 376 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More, Subregion 10

Name	Stream	Total Storage (ac-ft)	Active Storage (ac-ft)	Surface Area (acres)	Purpose1/
Clear Lake	Clear Cr.	-	7,135	-	M
Emigrant Lake	Emigrant Cr.	40,530	39,000	-	CFIR
Fish Lake	N.F. L. Butte Cr.	8,020	7,500	405	I
Fourmile Lake2/	Fourmile Cr.	13,300	13,300	900	I
Howard Pr. Lake2/	Grizzly Cr.	62,100	60,600	1,960	CFIPR
Hyatt2/	Keen Cr.	16,200	16,000	900	IP
Lemolo No. 1	N. Umpqua R.	13,560	12,520	490	P
Valsetz	S.F. Siletz R.	5,240	5,240	-	W
Willow Creek	Willow Cr.	7,500	7,500	320	MIP

1/ C-conservation, F-flood control, I-irrigation, M-municipal, P-power, R-recreation, W-industrial.
2/ Located outside subregion but releases imported for use in the subregion.

Channel Modification There has been very little channel modification, as lack of development along the streams has prevented economic justification. Dredging has been confined to the harbors along the coast and in the Columbia River.

Forecasting Forecasting is used to provide a maximum of stored water for irrigation, power generation, and municipal use. The Weather Bureau operates a general flood-warning system at times of major flooding.

Constraints There are no interstate compacts or international treaties that are concerned with runoff in the Coastal Subregion. However, there are restrictions involved in the operation of existing reservoirs.

The first consideration is to maintain, as nearly as possible, sufficient flow to satisfy prior water rights. The next requirement is the flow of water advocated by the Fish and Wildlife Service and the state fish and game commissions as adequate for the normal resident fish population and the anadromous fish runs. Municipal water needs must also be considered.

Water Rights

In that part of the Coastal Subregion located in the State of Washington, essentially Water Resource Inventory Areas 19 through 24 (figure 666), a total of 1,284 active surface water-right appropriation records, in permit and certificate stages, were on file with the Department of Water Resources on April 30, 1967. Prime rights in this area allow summer period diversions totaling 1,641.39 cfs of which consumptive diversions amount to 847.01 cfs, partially consumptive diversions are allowed up to 683.71 cfs and nonconsumptive diversions are permitted to 110.67 cfs. A total of 20.00 cfs has been appropriated under supplemental rights.

Reservoir storage rights on record with the Department of Water Resources permit a total of 201,460 acre-feet to be retained in storage annually in that part of the Coastal Subregion lying within the State of Washington.

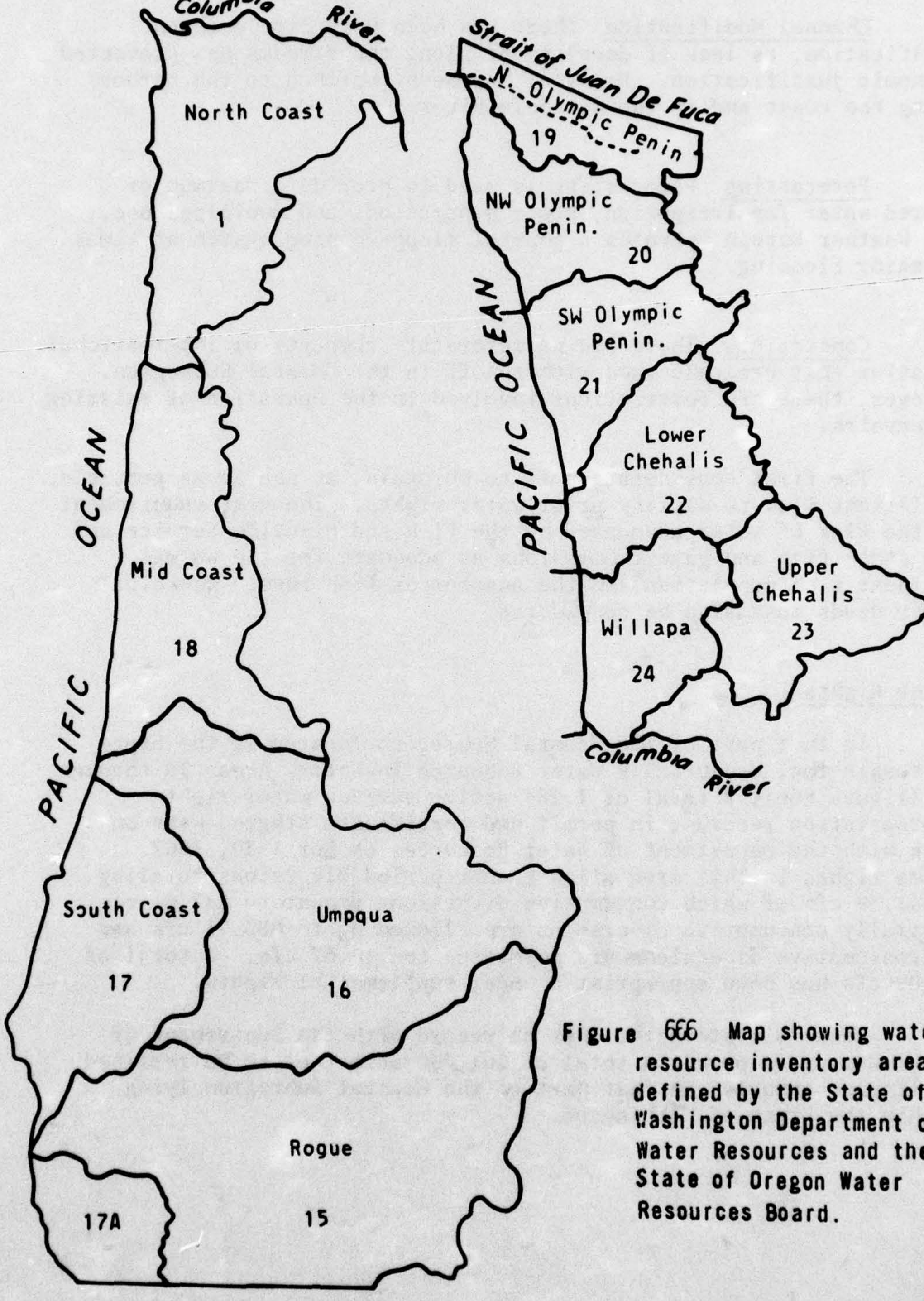


Figure 666 Map showing water resource inventory areas defined by the State of Washington Department of Water Resources and the State of Oregon Water Resources Board.

Table 377 - Surface Water Rights, Washington Part of the Coastal Subregion, 1967

Basin 1/ No.	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total 2/	Reservoir Storage Rights
		(Cubic Feet per Second)							(Acre-Feet)
Appropriative Rights									
19	N. Olympic Pen.	-	1.99	8.14	-	2.31	0.01	12.47	-
20	N.W. Olym. Pen.	1.50	2.10	3.46	2.95	35.00	0.02	48.55 3/	-
21	S.W. Olym. Pen.	-	0.16	2.83	0.01	0.10	0.01	13.56 4/	-
23	Upper Chehalis	418.93	48.81	23.86	189.35 5/	54.07	2.06	1,223.14 6/	201,159 7/
22	Lower Chehalis	39.10	137.38	7.88	12.71	11.75	2.29	207.81 8/	249
24	Willapa	11.33	73.80	7.00	34.79 9/	25.83	0.31	135.86	52
TOTAL		470.86	264.24	53.17	239.81	129.06	4.70	1,641.39	201,460

1/ Water Resource Inventory Area number as shown in figure 375.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.
3/ Includes 7.31 cfs for hydroelectric power generation.
4/ Includes 10.00 cfs for hydroelectric power generation.
5/ Includes 12.20 cfs for heat exchange.
6/ Includes 607.25 cfs for hydroelectric power generation.
7/ Includes a permit held by the city of Aberdeen to develop 200,000 acre-feet of storage on the Wynoochee River for municipal supply and hydroelectric power generation.
8/ Includes 13.32 cfs for hydroelectric power generation.
9/ Includes 13.89 cfs for heat exchange.

Prime water-right quantities for the more important use categories and total actual surface water-right quantities are listed in table 377 according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

Discharge

A typical Subregion 10 stream, Quinault River near Quinault Lake, Washington, shows a 30-year base-period (1929-58) mean discharge equal to 99 percent of its long-term mean (55 years, 1911-1965). Weather records show that precipitation in Aberdeen during the base period was 100 percent of the long-term mean (85 years, 1881-1965). Thus, the selected base period provides very good data for statistical analysis.

Measurement Facilities Table 378 summarizes pertinent streamflow data for the 21 sites selected for detailed study in Subregion 10. Figure 668 shows the locations of the selected sites, with Geological Survey identification numbers. The two leading digits in the identification number, part number, indicate the general area. Part Number (12) indicates that the site lies within the area designated Pacific slope basins in Washington and upper Columbia River Basin. Part Number (14) indicates that the site lies within the area designated Pacific slope basins in Oregon and lower Columbia River Basin.

Table 378. Streamflow Summary for Selected Sites, Subregion 10

Stream	Station	Station Number	Gage Datum (ft.)	Drainage Area (sq.mi.)	Period of Record	Annual Flows1/ (cfs) Mean	Max.	Min.	Momentary2/ Flow(cfs) Max.	Min.
Soleduck River	Fairholm	415	1,060	83.8	33-65 3/	597	832	359	23,500	51
Hoh River	Forks	410	320	208	26-64	1,991	2,576	1,396	38,700	247
Quinault River	Quinault Lake	395	184.60	264	11-65	2,766	3,571	1,780	50,200	276
Wynoochee River	Aberdeen	360	401	74.1	25-65	788	1,051	512	23,600	64
Satsop River	Satsop	350	0	299	29-65	1,944	2,643	1,238	46,600	166
Chehalis River	Grand Mound	275	123.27	895	28-65	2,761	4,444	1,569	48,400	90
North River	Raymond	170	7.39	219	27-65	941	1,610	589	35,000	21
Naselle River	Naselle	100	24	54.8	29-65	425	573	264	11,100	19
Nehalem River	Foss, Oregon	3,010	32.60	667	39-65	2,675	4,127	1,582	43,200	54
Wilson River	Tillamook	3,015	42.13	161	31-65 3/	1,171	1,696	734	32,100	45
Siletz River	Siletz	3,055	102.32	202	24-65 3/	1,521	2,168	879	32,200	48
Alsea River	Tidewater	3,065	48.16	334	39-65	1,545	2,384	881	41,800	45
South Umpqua River	Brockway	3,120	461.84	1,670	42-65 3/	2,667	5,362	907	105,000	36
North Umpqua River	Toketee Falls	3,135	4,025	170	27-65	414	555	295	4,680	9.7
Umpqua River	Elkton	3,210	90.42	3,683	05-65	7,353	13,350	3,150	265,000	640
S.F. Coquille River	Powers	3,250	197.42	169	30-65 3/	785	1,313	396	48,900	12
Coquille River	Coquille	3,251	-	943	-	3,129	5,267	1,569	-	-
Rogue River	Dodge Bridge	3,390	1,273.66	1,215	38-65	2,465	3,984	970	87,600	611
Rogue River	Grants Pass	3,615	885.28	2,459	38-65	3,235	5,938	1,156	152,000	195
Illinois River	Kerby	3,771	1,198.08	381	61-65 3/	1,208	2,088	576	92,200	23
Rogue River	Gold Beach	3,790	-	5,060	-	11,290	21,150	4,621	-	-

1/ Regulated values for base period (1929-58) with estimated 1970 conditions of development.
2/ Maximum and minimum observed instantaneous values for period of record.
3/ Denotes other short periods of record prior to dates shown.

Average Discharge for Subregion 10 Figure 667 presents monthly discharge data for the subregion as a whole. The discharge is generated entirely within the subregion; it rises to a maximum in January and recedes to a minimum in August and September. The within-area generated flows are also shown in table 379. Isopleths showing mean annual runoff for the period 1931-60 are shown on figure 668.

Table 379 - Discharge in Coastal Subregion 1929-58

(Mean Discharge, in cfs)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Mean
						Maximum							
Total	139,389	204,139	374,461	435,076	340,134	254,060	201,837	138,913	111,311	39,609	22,368	29,417	190,260
						20 Percent							
Total	56,748	168,189	219,134	249,909	216,476	172,812	125,102	97,675	66,216	33,114	20,466	19,996	119,978
						Mean							
Total	40,933	96,814	165,750	177,075	165,1[illegible]1	131,321	98,156	72,007	50,007	26,464	16,142	16,234	87,615
						80 Percent							
Total	21,142	53,621	109,684	103,818	118,286	90,156	70,068	51,907	32,906	20,139	13,220	12,661	57,813
						Minimum							
Total	12,079	9,887	48,157	53,718	59,506	58,996	46,554	32,578	20,519	13,873	11,207	10,565	31,345

Note: 1. Subregion discharge is that which originates in the subregion.
2. Twenty percent and 80 percent represent the discharge available 20 and 80 percent of the time.

Average Discharge for Selected Stations In this section of the report detailed data are presented for each of the selected sites listed in table 378.

The monthly discharges presented for stations in Washington are available in Geological Survey Water-Supply Papers 1316 and 1736, compilations of surface-water records in Part 12; and those

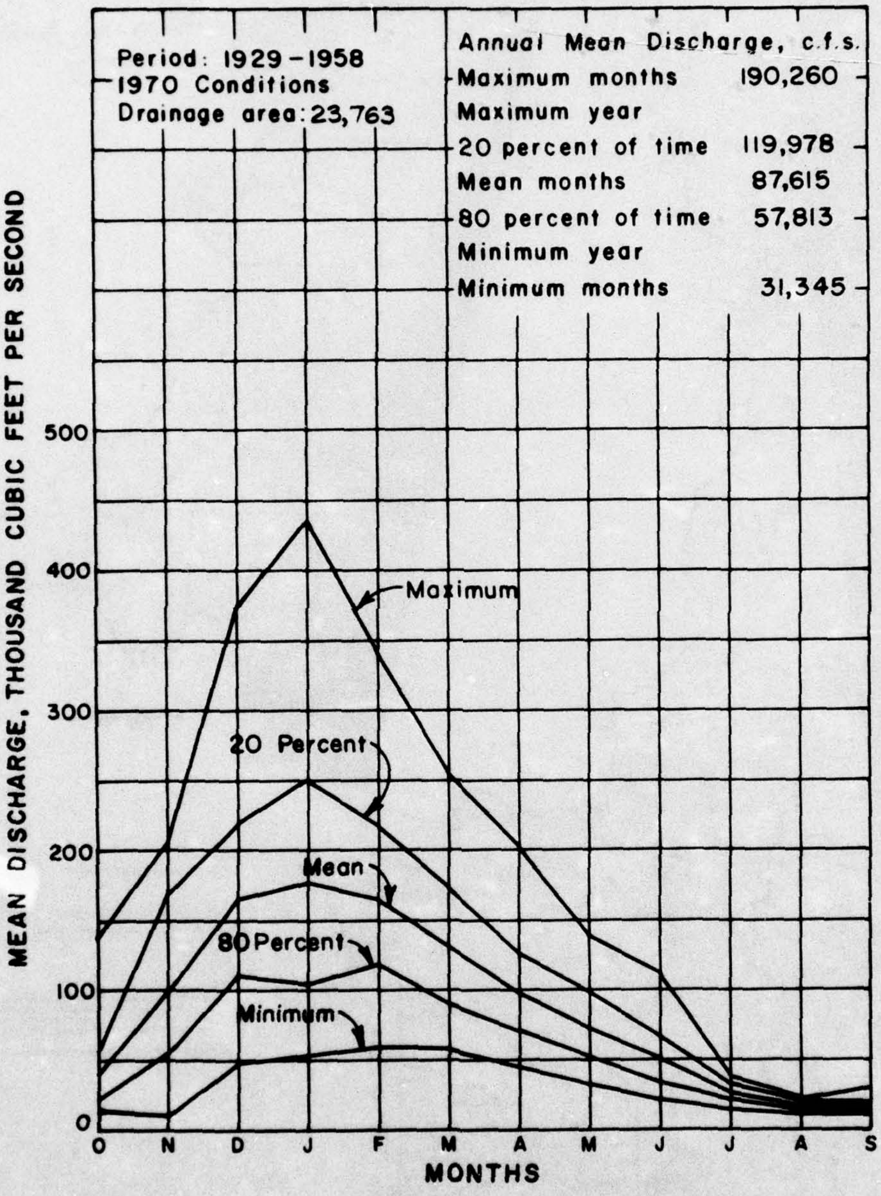
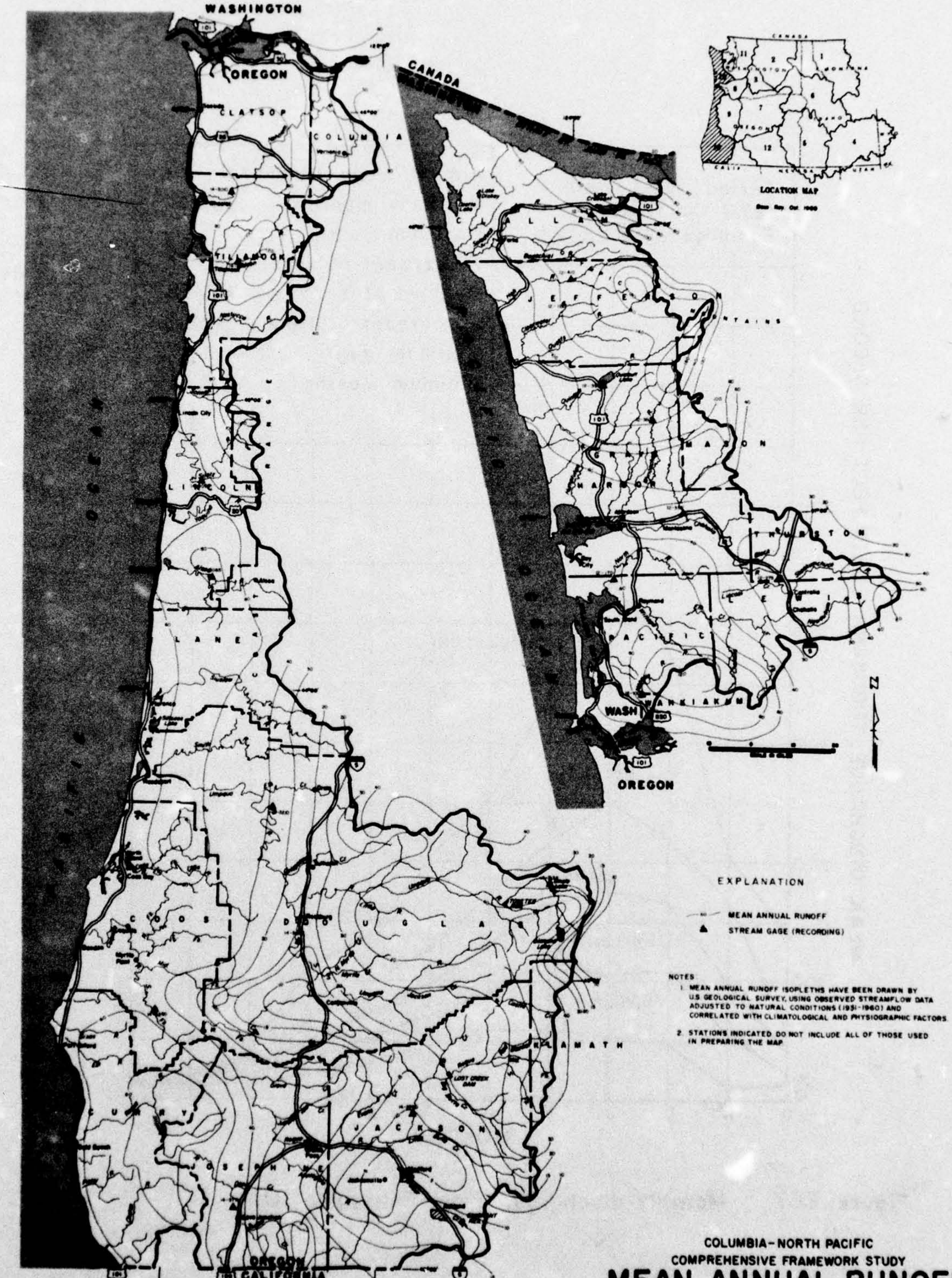


Figure 667. Monthly discharge, from Subregion 10.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

COASTAL SUBREGION 10

1968

FIGURE 668

for stations in Oregon are available in Water-Supply Papers 1318 and 1738, except for Coquille River at Coquille and Rogue River at Gold Beach, compilations in Part 14. Records for nearly half of the sites have been extended by correlation with nearby stations. Monthly discharges for all of the sites are listed in tables 380 to 400. Hydrographs for several conditions of flow at the selected sites are shown on figures 669 to 689. Explanations of these and the succeeding graphs are in the Regional Summary. The sustained flow of the Hoh, North Umpqua, and Rogue Rivers is notable.

Frequency curves of annual high and low discharges are shown on figures 690 to 710. The slopes of the curves are generally the same, showing that the range from high to low years is the same from one stream to another; the Rogue and South Umpqua Rivers show greater slopes for higher flows. The spacing of the curves is also generally uniform, showing seasonal consistency. The low-flow spacing is close for the Hoh River, all spacing is close for the Rogue River, and very close for the North Umpqua River.

Duration curves for three flow conditions, daily, monthly, and annual, are presented in figures 711 to 731. The monthly and annual discharges used are those of tables 380 to 400, but the daily flows are observed for the period of record as provided in the Geological Survey daily summaries. The curves are steep for the South Umpqua and Rogue Rivers and closely spaced for the Hoh, North Umpqua, and Rogue Rivers.

Frequency curves of annual peak flows are shown in figures 732 to 750. The range in peak flows from one stream to another is fairly constant, as indicated by the slopes of the curves. The South Umpqua and Rogue Rivers show the steepest slopes. Two of the frequency curves should be used with caution. That for North River near Raymond, figure 738, is an average of two types of flood conditions; the normal floods lie on a flatter curve, and the highest floods should be considered to fall along a steeper curve than shown. Further study will be required to determine the reason for this. The curve for North Fork Umpqua River below Lemolo Lake near Toketee Falls likewise is an average. Apparently, surface conditions, including a deep snowpack, normally check the flood peaks, but occasionally a great rain flood develops as in December 1964 after a severe freeze.

Dependable yields of the rivers are given in tables 401 to 421. Each table shows the lowest mean flows for from one to ten consecutive years in the 30-year base period and their relationship to the 30-year mean. The difference between any two flows is a measure of the reservoir storage capacity required to make the higher flow available. The South Umpqua and Rogue Rivers would require relatively more storage, with the South Umpqua River near Brockway, table 413, having a minimum-year flow of only 34 percent of the 30-year mean. On the other hand, the minimum-year flow of the North Umpqua River below Lemolo Lake near Toketee Falls, table 414, is 71 percent of the mean; and that for the Hoh River is nearly as high. The average minimum-year discharge in the subregion is about 57 percent of the mean.

Variations in Discharge Long-term variations in discharge and precipitation are presented in figures 751, 752, and 753 for a northern, a central, and a southern coastal stream. The annual means for the base period and for the entire period of record are shown. Although the annual precipitation for a given year varied from the mean by as much as 43 percent, the 5-year moving average varied from the mean by no more than 20 percent.

The 5-year moving averages are presented in order to indicate trends more clearly. There has been a general decline in precipitation and streamflow from about 1895 to about 1945, with an increase since then.

As indicated by the duration curves and frequency curves, the variation in annual flows at selected sites during the 30-year base period is generally relatively small, and uniform among the sites; that for the South Umpqua and Rogue Rivers is the greatest. The maximum annual discharge is generally about 1.8 times the minimum annual discharge, ranging from 1.4 for the Hoh and North Umpqua Rivers to 2.9 for the South Umpqua and the central part of the Rogue River.

Seasonal variations in runoff are clearly shown in the hydrographs of figures 669 to 689. For most of the hydrographs only one peak is shown, caused by winter rainfall. However, for streams draining the Olympic Mountains and for the upper Umpqua and Rogue Rivers there is a definite second peak in May and June from snowmelt. This is the primary peak for North Umpqua River below Lemolo Lake near Toketee Falls. The resulting low variation in monthly and seasonal flows is indicated by the close spacing of the frequency curves in figure 703 and the flat monthly duration curve of figure 724. The close spacing of frequency curves for low flows only of Hoh River near Forks indicates considerable underground storage release.

Streamflow Travel Time With the cooperation of several Federal and state agencies, time-of-travel studies have been made for a number of streams, including the Chehalis, Umpqua, and Rogue Rivers. Plots of accumulated time in hours versus river mile for various discharges are shown in figures 754, 755, and 756. The travel time for low and moderate discharges was determined by injections of rhodamine B dye downstream by visual observation and by fluorometer (optical instrument). The resulting velocity was reduced about 10 percent to obtain the average particle velocity through the river reach. High-flow travel time was determined by hydrograph inspection and flood routing computations and is based on velocity of the flood wave. Flows in the middle reaches of the Chehalis and Umpqua Rivers are slower than in downstream reaches. Travel times in minutes per mile for the lower 10 miles of all three rivers are as follows:

River	High Flow	Low Flow
Chehalis	-	156
Umpqua	50	96
Rogue	12	50

River Profiles Profiles for selected streams are shown on figures 757 to 764. The profiles were constructed mostly from topographic maps.

(Narrative continued on page 847)

Table 380. Observed Mean Discharge in c.f.s., Soleduck River near Fairholm, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										239	106	92	
1929	458	633	455	307	128	415	556	673	732	312	157	88	410
1930	151	69	629	326	1,440	586	826	406	371	153	116	146	418
1931	346	440	397	1,299	631	813	855	582	765	279	105	157	550
1932	293	932	820	764	1,024	1,026	841	543	645	419	189	107	631
1933	256	1,259	1,159	1,002	394	712	494	612	744	625	384	371	686
1934	732	702	2,495	1,747	652	882	520	570	254	171	108	107	750
1935	463	1,489	1,019	2,579	1,129	637	414	516	561	348	145	211	791
1936	227	318	567	1,070	382	717	570	796	717	343	126	129	498
1937	68	83	1,060	213	347	587	819	826	899	362	151	95	461
1938	388	1,341	1,446	868	372	614	657	564	444	207	97	76	591
1939	332	665	1,114	1,329	517	491	552	584	469	317	133	88	551
1940	193	723	1,981	939	1,025	997	439	620	209	107	76	67	615
1941	480	470	1,134	904	749	406	290	650	295	136	87	203	483
1942	629	802	1,439	407	439	331	399	387	504	266	111	72	483
1943	148	842	893	513	780	523	980	475	459	320	125	85	509
1944	263	314	654	1,010	412	350	359	354	270	122	73	124	359
1945	235	868	560	1,116	1,041	678	457	917	433	216	99	107	558
1946	379	1,038	1,156	981	703	744	740	869	738	489	215	121	681
1947	191	581	1,304	846	1,445	430	505	482	422	263	109	89	550
1948	797	669	1,139	852	766	465	514	987	857	364	210	296	660
1949	441	1,051	720	320	746	730	721	1,052	644	401	242	234	607
1950	407	1,469	1,606	712	1,109	870	821	756	1,166	658	298	145	832
1951	743	1,085	1,601	1,167	1,668	456	603	578	460	234	112	116	729
1952	653	808	649	438	819	333	572	712	561	358	168	103	513
1953	83	202	768	2,582	1,016	478	457	686	539	470	219	213	643
1954	578	1,177	1,575	1,057	1,726	575	596	662	659	607	334	218	808
1955	524	1,758	1,021	571	691	305	688	623	979	624	287	135	682
1956	641	1,622	957	769	258	565	803	1,036	1,090	638	224	247	738
1957	976	753	1,442	344	946	776	596	599	367	222	150	111	606
1958	232	388	1,039	1,375	1,132	465	579	509	356	148	80	122	532
Mean	410	818	1,093	967	816	559	607	654	587	339	164	146	597

Table 381. Observed Mean Discharge in c.f.s., Hoh River Near Forks, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										1,400	930	790	
1929	1,900	2,050	1,590	1,060	612	1,440	1,630	1,950	2,360	1,580	1,160	772	1,510
1930	910	503	2,010	1,110	4,050	1,760	2,330	1,250	1,490	1,180	999	1,030	1,530
1931	1,540	1,490	1,450	3,600	1,930	2,360	2,410	2,710	2,440	1,500	926	1,080	1,870
1932	1,370	2,990	2,470	2,230	2,960	2,880	2,370	1,610	2,150	1,840	1,250	859	2,080
1933	1,250	4,170	3,290	2,840	1,310	2,100	1,480	1,790	2,390	2,320	1,600	2,040	2,220
1934	2,887	2,318	6,543	4,805	1,970	2,406	1,730	1,801	1,218	1,394	1,205	867	2,442
1935	2,120	4,802	2,920	6,443	2,938	1,959	1,237	1,358	1,769	1,550	997	1,395	2,455
1936	1,074	1,000	1,954	3,220	1,244	2,184	1,616	2,608	3,069	1,999	1,182	982	1,850
1937	740	466	3,040	779	1,407	1,711	2,251	2,210	2,860	1,733	1,088	845	1,595
1938	1,799	3,937	3,618	2,199	1,212	1,715	1,796	1,611	1,698	1,357	816	865	1,889
1939	1,582	2,146	3,178	3,761	1,767	1,397	1,438	1,834	1,734	1,821	1,109	839	1,888
1940	1,125	2,604	5,381	2,842	2,861	2,545	1,361	2,157	1,208	1,067	947	849	2,081
1941	2,656	1,527	3,007	2,416	2,303	1,324	1,064	1,985	1,386	1,268	943	1,386	1,772
1942	2,561	2,582	3,939	1,267	1,387	1,031	1,181	1,372	2,103	1,799	1,096	699	1,756
1943	966	2,576	2,622	1,535	2,206	1,415	2,709	1,537	1,621	1,546	957	815	1,702
1944	1,317	1,141	2,283	2,782	1,313	1,173	1,171	1,250	1,311	1,032	790	1,161	1,396
1945	1,393	3,042	1,934	3,257	2,846	2,173	1,412	2,461	1,585	1,459	966	1,010	1,956
1946	1,482	3,222	3,144	2,725	2,024	2,306	2,086	2,298	2,356	2,070	1,270	822	2,152
1947	891	1,747	3,575	2,270	3,764	1,152	1,496	1,638	1,764	1,57[illegible]	934	823	1,790
1948	2,984	2,149	3,319	2,391	2,222	1,419	1,532	2,854	2,664	1,609	1,357	1,649	2,181
1949	1,682	3,895	2,492	889	2,427	2,155	1,832	2,776	1,928	1,611	1,363	1,233	2,018
1950	1,590	3,963	4,112	2,430	3,148	2,651	2,086	1,656	2,597	2,091	1,488	792	2,378
1951	2,362	2,836	4,348	3,200	4,625	1,504	1,571	1,522	1,590	1,291	823	934	2,203
1952	2,646	2,498	2,081	1,537	2,420	1,011	1,557	2,016	1,897	1,776	1,283	802	1,791
1953	577	857	2,492	7,092	3,234	1,529	1,368	2,074	1,675	1,893	1,275	1,157	2,102
1954	2,257	3,736	4,702	3,159	4,771	1,819	1,824	1,889	1,943	2,277	1,479	1,220	2,576
1955	2,339	5,912	2,859	1,638	1,895	1,094	2,051	1,498	2,563	2,193	1,410	930	2,194
1956	2,369	4,665	2,955	2,736	1,441	2,232	2,113	2,354	3,201	2,423	1,348	1,359	2,434
1957	3,076	2,078	3,892	1,260	2,479	2,431	1,714	1,973	1,656	1,509	1,176	1,026	2,023
1958	1,270	1,546	3,077	3,726	3,524	1,460	1,647	1,744	1,767	1,293	944	1,004	1,908
Mean	1,757	2,615	3,143	2,707	2,410	1,730	1,735	1,893	2,000	1,668	1,139	1,042	1,991

Table 382. Observed Mean Discharge in c.f.s., Quinault River at Quinault Lake, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										1,050	475	465	
1929	2,410	3,090	2,430	1,600	673	1,980	2,300	2,830	3,280	1,560	723	417	1,950
1930	656	484	2,960	1,530	5,420	2,140	3,410	1,760	1,570	855	428	519	1,780
1931	1,740	2,240	2,190	5,890	3,090	3,860	3,690	2,440	2,900	1,370	539	841	2,560
1932	1,960	3,560	4,010	3,640	4,250	4,350	3,720	2,610	3,020	2,250	1,180	657	2,930
1933	1,110	5,270	5,160	4,590	2,170	3,200	2,400	2,960	3,690	3,340	1,650	1,370	3,080
1934	3,205	4,056	10,260	7,246	3,072	3,670	2,432	2,419	1,116	1,561	876	689	3,400
1935	2,963	6,269	4,315	9,285	4,189	3,111	1,706	2,310	2,611	1,754	742	1,452	3,390
1936	1,257	1,516	3,205	4,866	1,844	2,912	2,119	3,880	3,939	1,824	691	700	2,403
1937	523	410	4,345	1,177	1,889	2,844	3,780	3,841	4,662	2,088	923	645	2,262
1938	2,557	6,868	5,832	3,486	1,938	2,840	3,002	2,651	2,325	1,251	528	411	2,811
1939	1,596	3,365	4,370	6,157	2,581	1,942	2,096	2,608	2,166	1,657	752	628	2,497
1940	1,307	3,545	8,173	4,457	4,847	3,998	2,267	3,053	1,261	649	500	504	2,880
1941	3,906	2,828	4,318	3,681	3,209	2,418	1,925	2,896	1,538	778	448	1,728	2,472
1942	3,056	3,477	6,219	1,901	2,485	1,532	1,818	2,045	2,814	1,679	687	403	2,344
1943	593	3,771	3,632	2,178	2,823	2,250	4,484	2,156	2,187	1,566	709	470	2,225
1944	1,456	1,676	3,364	4,013	2,250	1,874	1,779	1,861	1,591	738	422	780	1,818
1945	1,298	4,653	2,968	4,804	4,807	2,871	1,776	3,945	2,155	1,361	591	847	2,659
1946	1,710	4,655	4,745	4,225	2,941	3,377	3,294	3,615	3,557	2,801	1,193	746	3,073
1947	1,228	2,765	5,718	3,622	6,141	1,994	2,433	2,245	1,954	1,382	687	681	2,548
1948	4,569	3,050	4,754	3,360	2,860	2,016	2,597	4,575	3,959	1,806	1,008	2,006	3,049
1949	2,362	3,984	3,568	1,392	3,457	3,615	2,823	4,428	2,760	1,927	1,255	1,256	2,730
1950	1,841	6,678	6,199	3,495	4,491	4,417	3,221	2,794	4,115	3,072	1,771	870	3,571
1951	3,743	4,899	7,752	4,825	7,181	1,892	2,394	2,715	2,224	1,232	571	556	3,309
1952	3,735	3,349	3,241	2,114	3,905	1,655	2,550	3,681	3,007	2,140	1,142	686	2,596
1953	414	1,153	3,356	11,390	5,216	2,054	2,059	3,399	2,534	2,452	1,224	854	3,006
1954	2,754	5,858	6,743	4,500	6,694	2,774	2,717	2,458	2,723	2,999	1,518	1,247	3,561
1955	3,244	8,465	4,116	2,568	3,072	1,438	3,144	2,234	3,735	2,893	1,691	845	3,111
1956	3,735	7,592	4,389	3,809	1,695	2,983	3,034	3,888	5,116	3,396	1,370	1,242	3,525
1957	4,347	2,966	6,229	1,687	3,829	3,729	2,822	2,879	1,980	1,374	1,041	644	2,795
1958	1,189	2,327	4,682	5,985	5,962	2,344	2,771	2,612	2,071	900	453	547	2,634
Mean	2,203	3,827	4,775	4,116	3,633	2,736	2,684	2,926	2,752	1,822	910	841	2,766

Table 383. Observed Mean Discharge in c.f.s., Wynoochee River above Save Creek near Aberdeen, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										187	132	151	
1929	747	955	880	514	247	708	796	590	590	228	133	97	542
1930	187	137	1,010	469	1,720	667	969	408	271	153	97	155	512
1931	392	590	608	2,080	983	1,320	1,210	386	550	256	127	299	732
1932	719	1,320	1,670	1,260	1,550	1,520	1,240	612	475	372	235	140	923
1933	343	1,684	1,321	1,465	722	1,274	836	979	764	485	212	551	887
1934	946	960	3,472	2,529	878	1,132	537	529	183	263	188	146	987
1935	910	2,049	1,388	3,473	1,303	1,214	614	511	404	226	150	369	1,051
1936	308	475	1,102	1,769	740	938	522	772	758	411	171	176	680
1937	140	112	1,395	339	644	1,140	1,494	1,055	919	303	174	141	655
1938	809	2,219	1,841	1,082	763	1,021	972	527	292	149	102	95	822
1939	549	923	1,259	1,890	926	682	548	494	327	229	131	146	675
1940	356	999	2,452	1,265	1,663	1,225	580	623	187	127	115	122	809
1941	1,185	859	1,390	1,274	960	714	466	681	279	161	146	533	721
1942	812	1,091	1,837	654	869	519	486	444	588	375	176	120	664
1943	209	1,364	1,632	832	1,730	1,032	1,348	447	342	198	138	119	775
1944	412	428	1,016	1,333	732	615	621	419	257	134	104	197	523
1945	309	1,374	811	1,477	1,867	1,306	600	1,019	344	188	104	210	794
1946	409	1,423	1,612	1,394	1,187	1,220	1,130	636	506	406	166	161	952
1947	280	894	1,468	1,271	1,885	565	661	404	329	345	165	201	698
1948	1,548	882	1,583	1,152	965	712	896	1,272	587	249	186	574	885
1949	594	1,320	1,058	246	1,216	1,250	844	848	420	266	191	232	703
1950	473	1,943	2,071	1,230	1,736	1,692	1,055	680	662	344	281	153	1,021
1951	1,129	1,456	2,143	1,501	1,966	632	705	540	236	144	207	236	894
1952	1,228	1,150	1,060	941	1,394	646	840	803	521	274	254	180	774
1953	138	407	1,358	3,953	1,536	665	625	794	456	304	181	270	890
1954	672	1,523	1,970	1,500	2,393	939	883	467	453	433	194	247	963
1955	700	2,542	1,274	882	1,083	613	1,061	607	575	456	311	219	856
1956	1,098	2,457	1,511	1,410	463	1,290	1,078	836	968	495	208	302	1,010
1957	1,224	883	2,335	895	1,652	1,313	834	485	274	274	269	156	880
1958	404	664	1,503	1,966	1,894	698	887	433	248	143	112	161	753
Mean	641	1,169	1,534	1,402	1,256	921	845	629	459	280	174	224	788

Table 384. Observed Mean Discharge in c.f.s., Satsop River near Satsop, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										405	271	287	
1929	1,210	1,721	2,968	1,984	2,048	2,715	2,490	992	794	413	284	227	1,487
1930	314	280	2,030	1,540	4,850	1,890	2,050	894	556	342	250	296	1,250
1931	678	1,340	1,410	4,740	2,820	3,650	3,170	674	1,390	587	321	590	1,770
1932	1,990	3,750	4,970	4,690	4,750	4,960	3,180	888	488	422	372	273	2,560
1933	523	3,700	4,030	4,510	2,800	4,130	1,820	1,640	870	445	293	809	2,130
1934	2,062	2,481	9,296	6,413	2,269	2,787	1,187	976	420	462	314	327	2,432
1935	1,808	4,200	3,913	9,002	2,986	3,166	1,508	830	501	329	242	451	2,415
1936	491	1,006	2,298	5,807	2,677	2,980	1,112	1,178	1,328	645	317	374	1,687
1937	315	268	3,318	1,276	3,558	2,977	4,038	1,671	1,382	578	355	266	1,653
1938	1,703	6,372	5,060	3,567	2,821	3,324	2,702	1,031	510	351	258	208	2,320
1939	654	1,913	2,768	5,035	3,341	2,199	928	711	600	367	253	281	1,580
1940	691	1,637	5,069	2,973	4,728	3,097	1,770	1,435	438	313	272	261	1,884
1941	1,739	2,065	3,097	3,451	1,990	1,478	910	1,330	563	330	278	892	1,511
1942	1,258	2,149	4,483	1,654	2,546	1,513	898	870	968	654	345	246	1,461
1943	409	3,235	3,756	2,047	3,766	2,023	2,888	944	657	422	303	243	1,707
1944	642	841	2,789	3,032	1,996	1,674	1,726	832	474	289	225	336	1,238
1945	421	2,653	1,916	4,046	4,210	3,829	1,784	1,649	596	346	265	373	1,827
1946	702	3,449	4,333	4,206	4,048	3,661	3,029	958	614	619	309	269	2,171
1947	681	2,344	4,090	4,073	4,983	1,601	1,769	855	555	462	282	356	1,818
1948	2,825	1,967	3,370	3,341	3,037	2,287	2,071	2,696	669	397	352	929	1,996
1949	1,153	3,743	4,619	1,127	4,794	3,291	1,545	1,355	488	351	284	338	1,905
1950	837	4,246	5,228	3,722	6,122	5,983	2,848	1,246	644	383	390	320	2,643
1951	1,862	3,935	6,107	5,343	6,752	2,362	1,321	742	430	287	231	314	2,449
1952	2,176	2,373	3,064	2,760	3,744	1,841	1,660	1,061	601	341	357	289	1,683
1953	244	553	3,017	9,598	4,688	1,848	1,387	1,425	737	415	291	317	2,036
1954	1,004	3,211	5,345	4,733	6,672	2,451	2,205	688	588	550	346	432	2,325
1955	1,092	4,786	3,163	2,892	2,938	2,128	3,499	1,116	575	542	508	348	1,954
1956	2,490	5,845	5,404	4,998	1,843	4,914	2,388	913	1,033	471	317	447	2,595
1957	2,541	2,162	4,575	1,632	3,544	3,710	1,987	724	464	412	419	294	1,865
1958	623	1,376	3,799	4,644	4,211	1,830	2,250	752	426	300	242	294	1,715
Mean	1,171	2,653	3,976	3,961	3,718	2,877	2,072	1,106	679	428	309	380	1,944

Table 385. Observed Mean Discharge in c.f.s., Chehalis River near Grand Mound, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										332	197	189	
1929	549	1,100	2,740	2,800	2,300	3,940	4,390	1,240	900	405	193	197	1,730
1930	272	326	2,890	2,070	6,830	3,100	1,570	1,200	710	287	155	189	1,600
1931	350	1,200	1,230	5,650	3,860	4,460	5,180	709	885	409	235	314	2,030
1932	1,470	4,120	5,610	6,030	6,650	7,340	4,320	1,110	588	399	252	242	3,170
1933	532	7,540	9,150	8,260	4,370	6,930	2,380	1,760	1,120	436	295	650	3,620
1934	1,790	2,792	19,280	9,445	2,020	3,453	1,565	891	353	243	189	229	3,558
1935	2,457	9,192	7,475	9,647	3,946	5,127	2,038	745	414	262	171	283	3,482
1936	294	837	1,921	10,320	5,141	5,522	1,577	1,567	2,482	550	264	268	2,561
1937	224	221	3,777	2,160	7,859	4,251	6,787	1,570	1,902	604	312	357	2,460
1938	664	8,107	8,822	5,817	4,193	5,290	3,366	983	381	223	159	131	3,172
1939	374	2,098	3,581	6,401	8,174	3,664	1,086	549	650	330	189	172	2,238
1940	291	497	5,812	3,803	9,067	5,422	3,205	2,870	489	259	160	214	2,656
1941	735	2,139	3,785	4,627	1,884	1,462	1,098	1,451	640	299	212	786	1,596
1942	1,051	3,278	8,181	2,812	4,209	2,226	1,134	1,233	1,589	625	282	180	2,225
1943	249	5,551	5,936	4,107	6,935	2,687	4,161	1,123	762	369	254	208	2,661
1944	615	1,018	3,115	4,153	3,232	2,281	2,406	887	571	240	154	193	1,569
1945	284	1,866	1,850	4,813	6,226	6,151	2,577	1,951	572	256	173	368	2,235
1946	298	3,675	5,453	7,870	7,731	4,583	2,600	840	710	609	237	257	2,878
1947	1,043	5,365	8,042	5,109	6,497	2,569	2,403	710	536	300	172	286	2,728
1948	2,429	4,636	4,531	6,863	6,400	4,272	3,389	3,496	821	348	273	469	2,152
1949	995	5,268	10,260	2,131	11,060	3,956	1,568	1,414	426	243	173	172	3,088
1950	502	4,175	7,414	8,138	10,680	8,497	3,832	1,238	536	265	274	209	3,774
1951	2,110	7,087	8,545	9,597	9,289	5,048	1,834	819	356	182	123	155	3,732
1952	2,137	3,776	6,909	4,417	6,054	3,071	1,886	955	436	257	153	135	2,507
1953	125	257	2,454	12,800	6,298	2,734	1,752	1,571	882	361	248	218	2,462
1954	1,097	3,753	9,070	9,070	11,100	3,163	3,452	766	1,033	538	312	481	3,662
1955	854	4,058	4,227	5,098	4,362	4,877	5,554	1,590	717	534	297	319	2,694
1956	2,630	9,697	12,400	9,791	3,829	9,060	3,343	826	803	322	228	229	4,444
1957	1,580	2,542	5,987	2,253	6,030	6,470	2,746	971	556	305	245	155	2,468
1958	399	1,488	6,595	6,465	6,911	2,645	3,806	967	589	229	129	184	2,509
Mean	937	3,589	6,235	6,089	6,098	4,475	2,900	1,267	780	353	217	242	2,761

Table 386. Observed Mean Discharge in c.f.s., North River near Raymond, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										113	60	62	
1929	455	774	1,060	906	749	1,330	1,430	482	316	135	85	62	648
1930	75	74	935	868	2,500	1,040	829	436	251	107	85	84	594
1931	216	574	640	1,840	1,260	1,680	2,110	273	393	214	85	227	789
1932	1,470	1,880	2,220	2,400	2,780	2,630	1,560	376	175	115	112	98	1,310
1933	238	2,610	2,920	3,000	1,710	2,090	724	591	381	135	78	334	1,230
1934	1,046	1,356	9,450	3,542	833	1,351	611	445	163	125	77	114	1,610
1935	1,070	2,321	2,412	4,088	1,256	1,942	597	265	151	104	58	118	1,202
1936	114	346	766	2,948	1,441	1,689	480	421	511	222	87	92	760
1937	74	65	1,315	700	2,723	870	2,033	584	499	193	115	118	759
1938	400	3,201	3,306	1,734	1,401	1,501	1,138	346	121	66	47	34	1,105
1939	209	1,110	1,405	2,317	2,504	1,190	309	236	299	140	63	63	811
1940	155	361	2,157	1,286	2,575	1,642	1,021	940	144	73	59	73	870
1941	629	994	1,297	1,434	665	486	282	519	209	84	83	375	589
1942	530	1,035	2,468	840	1,257	839	433	450	627	224	98	58	720
1943	162	1,917	2,025	1,061	1,864	836	1,372	344	209	110	83	66	828
1944	325	438	1,524	1,408	989	773	906	349	169	83	51	92	592
1945	133	1,053	818	1,459	1,739	1,726	743	616	202	82	43	136	723
1946	168	1,540	2,128	2,269	2,328	1,574	1,180	304	217	175	74	85	995
1947	330	1,384	2,326	1,764	2,129	628	674	229	210	124	72	74	821
1948	1,220	1,761	1,559	1,849	1,834	1,376	1,010	1,127	245	112	89	228	1,032
1949	495	1,749	3,015	680	3,002	1,023	456	451	135	80	57	63	920
1950	275	1,702	2,710	2,800	3,040	2,754	1,222	416	173	99	104	92	1,273
1951	804	2,052	2,838	2,960	3,370	1,650	531	241	115	54	31	78	1,215
1952	1,177	1,185	1,980	1,567	1,708	890	608	351	161	79	64	46	817
1953	42	120	1,292	4,649	2,289	940	622	592	314	13	90	80	926
1954	346	1,434	2,958	2,926	3,247	1,064	1,021	254	279	192	150	378	1,175
1955	494	1,682	1,436	1,479	1,419	1,522	1,827	416	191	175	131	94	901
1956	1,112	2,734	3,151	2,756	1,367	2,882	848	210	329	115	76	107	1,310
1957	1,154	1,187	2,305	811	1,771	1,899	911	318	170	99	80	52	893
1958	206	616	2,047	2,187	2,121	894	1,129	342	184	71	45	101	822
Mean	504	1,309	2,215	2,018	1,929	1,424	954	424	251	116	79	121	941

Table 387. Observed Mean Discharge in c.f.s., Naselle River near Naselle, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										60	39	42	
1929	305	435	544	403	330	581	585	171	209	82	41	30	310
1930	33	38	476	360	1,040	458	315	220	143	63	33	40	264
1931	111	342	344	901	486	822	626	100	235	115	42	127	353
1932	563	863	1,040	1,030	1,020	1,070	689	131	68	73	76	51	556
1933	135	1,340	1,220	1,050	871	1,080	331	354	211	67	42	198	573
1934	508	516	2,530	1,350	294	539	241	213	78	73	51	58	543
1935	584	1,033	999	1,608	544	766	243	114	73	63	44	88	515
1936	90	294	476	1,338	616	644	188	256	278	156	55	52	371
1937	43	37	668	340	1,105	489	858	288	251	95	72	75	355
1938	322	1,488	1,002	618	510	661	548	189	64	38	31	29	457
1939	156	663	653	1,022	1,020	508	120	90	160	94	44	36	377
1940	129	307	1,226	555	1,154	693	361	331	63	44	40	43	410
1941	454	502	605	649	318	194	139	276	111	54	47	313	305
1942	335	535	1,119	315	661	335	188	218	289	135	59	35	350
1943	164	940	974	419	940	354	574	181	118	68	57	39	398
1944	289	334	694	570	455	397	455	139	81	44	33	73	297
1945	118	694	439	955	739	953	338	306	91	42	28	106	399
1946	100	972	1,052	1,045	1,200	719	559	120	125	149	50	50	507
1947	328	884	1,075	727	896	264	303	118	146	113	56	80	413
1948	796	810	737	813	748	489	448	448	102	56	50	176	472
1949	326	929	1,244	246	1,408	448	197	217	66	42	34	34	426
1950	177	876	958	914	1,532	1,217	527	193	78	47	62	52	547
1951	458	927	1,263	1,128	1,256	503	201	116	61	36	26	76	500
1952	727	561	781	767	797	543	267	113	94	55	46	36	400
1953	38	10	738	1,969	757	471	262	287	139	71	56	67	413
1954	260	735	1,106	1,045	1,412	403	464	98	197	131	86	111	498
1955	242	847	640	584	559	550	770	186	96	124	101	71	396
1956	526	1,166	1,262	1,092	502	1,213	315	82	215	73	48	87	550
1957	639	478	930	309	817	743	402	107	75	66	98	43	390
1958	159	429	1,035	943	1,007	332	560	125	73	38	28	55	395
Mean	304	666	928	836	833	615	403	193	133	77	51	78	425

Table 388. Observed Mean Discharge, in CFS, Nehalem River near Foss, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										190	90	98	
1929	540	2950	4083	4608	2100	3025	5747	890	800	365	117	82	2109
1930	220	70	4277	2765	11750	3350	2325	1790	600	169	114	89	2293
1931	180	1120	1531	4282	1750	5100	4650	620	555	253	173	115	1694
1932	1160	5150	5262	7315	4400	10200	3832	850	355	153	105	68	3237
1933	370	4800	8694	8390	7000	7450	2585	3860	1580	266	137	408	3795
1934	1370	2280	13777	8632	970	3500	1938	740	300	116	98	71	2816
1935	1570	7800	6424	5359	2250	4700	2319	850	360	174	99	98	2667
1936	200	950	2540	10685	3450	3230	1536	1570	745	311	153	102	2123
1937	110	80	3951	3039	7130	3630	6622	1470	1620	394	169	94	2359
1938	570	7930	9245	5818	5800	8000	3277	920	350	126	83	65	3515
1939	220	2550	3529	4620	8450	3330	967	460	425	199	108	74	2078
1940	224	368	6297	4267	8919	4559	2307	2415	356	167	108	131	2494
1941	385	1823	3753	5105	1999	1518	1149	1516	577	221	163	751	1582
1942	1218	3170	8572	2740	5234	2165	1250	1324	1099	433	194	121	2279
1943	237	6719	7208	4294	7659	2650	4300	1032	595	279	179	133	2902
1944	874	1439	3302	3872	3079	2510	2487	907	555	214	125	132	1622
1945	193	1609	1430	4563	5870	6941	3583	1684	586	197	112	321	2236
1946	197	5621	7061	7714	7491	4555	2398	750	455	402	150	133	3051
1947	886	6340	8362	4455	5855	2501	1508	535	551	299	155	181	2699
1948	2948	5337	3857	6375	6753	3859	3147	3028	655	281	183	227	3042
1949	676	4204	9134	1964	12490	3692	1314	1459	354	203	124	108	2915
1950	354	3530	5839	8028	11110	7739	3707	1159	427	207	135	107	3484
1951	1584	5621	7378	9407	7242	4706	1844	779	326	144	80	92	3249
1952	2320	3602	7173	4403	6120	3773	1764	856	381	183	98	78	2555
1953	70	197	3046	11720	5180	3604	2108	1735	826	343	182	159	2426
1954	835	3129	8166	9362	10030	2925	3567	625	698	402	190	246	3309
1955	702	3430	4405	5128	4125	4717	4847	1440	533	383	178	199	2497
1956	2511	8899	11390	9695	3863	8696	2768	594	453	199	159	153	4127
1957	1065	2048	4709	2176	5921	5504	2965	881	465	233	173	104	2165
1958	242	1423	7817	6605	7324	2453	4407	948	542	191	86	100	2652
Mean	801	3473	6074	5913	6044	4486	2907	1256	604	250	138	158	2675

Table 389. Observed Mean Discharge, in CFS, Wilson River near Tillamook, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										101	71	80	
1929	342	1602	1763	1824	1026	1392	2534	401	460	258	83	86	981
1930	134	60	1847	1094	4104	1552	1025	889	355	119	81	94	946
1931	112	704	661	1695	912	2240	2050	252	330	179	98	121	779
1932	804	2250	2240	2750	2210	3320	1820	428	187	122	99	76	1360
1933	197	2970	3410	2920	2020	2890	1260	1390	876	208	118	397	1550
1934	1192	1149	7988	3722	718	1764	914	744	191	131	98	124	1579
1935	2087	3975	3091	3068	1549	2039	1131	438	196	171	106	132	1500
1936	216	794	1446	4527	2044	1668	633	932	470	266	142	120	1106
1937	88	87	2133	940	2658	2101	2550	876	637	304	169	120	1044
1938	430	3621	4000	2145	1588	2269	1445	439	183	111	78	75	1364
1939	222	1453	1744	2041	2659	1541	426	202	252	156	89	74	894
1940	271	422	3056	1527	3301	1858	926	873	181	108	79	77	1051
1941	346	1104	1430	2064	751	595	489	704	285	146	120	765	734
1942	781	1443	3119	1015	1778	943	563	617	577	278	141	95	942
1943	213	3280	3178	1647	2921	1407	1758	476	389	183	121	89	1291
1944	487	784	1666	1541	1380	1072	1165	402	359	133	86	101	763
1945	167	1149	852	2246	2535	2497	1398	896	268	127	91	432	1045
1946	206	3086	3105	3006	2736	1990	1115	352	264	298	120	97	1356
1947	615	2750	3709	1933	2233	1211	938	273	457	222	123	230	1218
1948	2230	2278	1648	2437	2596	1603	1539	1386	312	153	109	169	1368
1949	581	2216	3487	694	4268	1718	715	920	186	124	91	91	1238
1950	455	2332	2497	3055	3506	3294	1790	660	238	126	107	93	1501
1951	1285	2610	3097	3498	2944	1664	852	445	200	104	69	111	1399
1952	1942	1808	2717	1699	2453	1515	939	446	213	127	83	67	1165
1953	58	146	1718	5776	2314	1495	872	916	405	191	155	141	1182
1954	599	1950	3686	3413	3540	1215	1489	269	469	266	139	159	1420
1955	613	1922	1909	1781	1834	1930	2069	821	287	202	117	122	1128
1956	1588	3935	4368	3476	1130	3637	1238	317	268	126	104	88	1696
1957	705	1033	2398	818	2394	2170	1059	429	317	177	133	81	968
1958	198	932	3740	3036	2884	909	1943	400	201	102	68	69	1198
Mean	369	1795	2723	2380	2333	1850	1223	620	334	174	107	150	1171

Table 390. **Observed** Mean Discharge, in CFS, Siletz River at Siletz, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										135	95	93	
1929	450	1930	2320	2400	1350	1740	3090	528	641	344	110	100	1250
1930	176	72	2430	1440	5400	1940	1250	1170	441	159	108	109	1200
1931	147	848	870	2230	1200	2800	2500	332	400	239	163	140	988
1932	1040	3220	2990	3810	2320	4560	2060	506	215	144	99	83	1750
1933	304	3010	4940	4370	3410	3720	1390	2580	1410	251	129	498	2168
1934	1255	1522	7828	4496	758	2002	1042	417	170	109	92	86	1666
1935	1487	4770	3650	2791	1429	2622	1247	501	219	164	93	119	1592
1936	158	755	1443	5565	1927	1854	826	1017	584	293	144	124	1227
1937	87	80	2245	1583	3460	2080	3560	944	1340	372	159	115	1318
1938	475	4841	5253	3030	2901	3885	1762	557	209	119	78	79	1927
1939	182	1694	2005	2406	4003	1912	520	233	275	188	102	90	1116
1940	344	373	3502	2028	4712	2704	1216	1165	215	120	79	83	1370
1941	290	1368	1821	2792	930	557	566	884	319	153	106	763	879
1942	610	1828	4406	1466	2458	1192	632	859	605	354	167	106	1218
1943	164	4754	4681	2557	3652	1959	2159	613	571	244	171	125	1788
1944	1147	1217	1944	1714	1858	1400	1416	514	553	174	106	98	1009
1945	134	1257	1133	3201	3439	2738	1879	1521	348	157	103	380	1345
1946	169	3637	3996	3734	3260	2738	1141	374	354	424	164	142	1669
1947	1014	3600	5123	2273	2763	1626	1310	356	876	335	198	248	1636
1948	3022	2866	1735	2998	3201	2013	2079	1543	317	182	132	150	1682
1949	712	2125	4769	1055	6055	1723	741	1299	259	170	129	154	1571
1950	488	2437	3135	4444	4724	3888	1632	782	281	144	117	113	1833
1951	1630	3745	4184	5230	3045	2215	997	894	285	148	90	157	1882
1952	2918	1833	3560	2698	3539	2152	1190	511	238	143	97	81	1577
1953	74	163	1933	7664	3865	2328	1099	1415	665	229	171	157	1641
1954	651	3170	5012	3989	4088	1680	1980	371	682	394	208	255	1859
1955	638	1739	2629	2207	2165	2532	2745	846	337	252	152	232	1368
1956	2015	4447	5073	5427	1955	4302	1428	454	286	148	99	102	2152
1957	802	1044	3178	1188	2742	3182	1413	563	344	197	149	83	1234
1958	266	1216	4756	3365	4047	1276	2492	511	222	120	76	117	1524
Mean	762	2185	3418	3138	3022	2377	1579	809	455	216	126	167	1521

Table 391. Observed Mean Discharge, in CFS, Alsea River near Tidewater, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										130	92	80	
1929	261	1325	2050	2743	1499	1931	3430	528	622	334	107	86	1243
1930	102	60	2150	1646	5994	2153	1388	1170	428	154	105	93	1287
1931	85	530	720	2548	1332	3108	2775	332	388	232	158	112	1027
1932	603	2400	2740	4354	2575	5062	2287	506	209	140	96	75	1754
1933	176	2240	4950	4994	3785	4129	1543	2580	1368	243	125	282	2201
1934	728	1000	8700	5138	841	2222	1157	417	165	106	89	75	1720
1935	862	3920	3450	3190	1586	2910	1384	501	212	159	90	100	1530
1936	92	460	1220	6360	2139	2058	917	1017	566	284	140	102	1280
1937	50	70	1970	1809	3841	2309	3952	944	1300	361	154	95	1405
1938	276	4000	5350	3463	3220	4312	1956	557	203	115	76	72	1967
1939	106	1150	1750	2750	4443	2122	577	233	267	182	99	75	1146
1940	159	115	2232	2007	4550	2808	1154	911	254	132	82	91	1198
1941	201	1027	1974	3068	1035	604	695	920	309	154	116	452	881
1942	274	1404	4271	2004	3063	1019	636	710	470	250	138	97	1185
1943	112	3578	5261	3885	3635	1775	2313	615	430	195	143	98	1825
1944	738	969	1695	1647	1704	1557	1507	595	379	171	109	95	928
1945	101	702	802	2394	3809	3407	2002	1536	494	197	119	156	1294
1946	102	2773	3815	3879	3376	2574	995	412	288	205	110	131	1545
1947	495	3477	4137	1778	2912	2039	1494	404	666	245	165	142	1485
1948	2521	2624	1814	4222	3308	2352	2238	1465	486	231	147	138	1792
1949	236	1313	4566	1380	6586	1669	741	1097	293	162	108	102	1490
1950	152	1174	2245	5533	5569	3742	1394	711	302	159	105	97	1745
1951	1419	4134	3976	6119	3940	3140	994	829	319	170	91	83	2094
1952	1600	2494	4936	4092	4142	2708	1038	472	285	183	109	86	1842
1953	77	151	1613	7874	3879	2896	1287	1549	724	269	189	134	1715
1954	387	2782	5291	5654	4876	2061	2130	460	323	191	138	159	2022
1955	361	1451	2691	2701	2001	3132	3173	899	320	219	109	139	1430
1956	1002	3929	6765	6734	3234	4375	1487	441	248	138	90	94	2384
1957	391	652	2205	1488	3066	3976	1551	698	367	191	135	94	1226
1958	191	534	4000	3720	4890	1770	2270	692	323	150	84	94	1542
Mean	462	1745	3311	3642	3361	2664	1682	807	434	197	118	122	1545

Table 392. Observed Mean Discharge, in CFS, South Umpqua River near Brockway, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										160	100	100	
1929	200	300	700	2180	2600	2600	4560	1240	785	160	85	70	1290
1930	150	100	3480	2500	7200	1600	900	910	382	115	75	80	1458
1931	180	450	540	1650	1150	3000	3050	460	190	100	60	60	907
1932	300	1220	3300	5900	4000	9400	3350	2310	1120	220	120	95	2611
1933	230	810	3200	6780	5350	4850	3400	3440	2120	420	150	130	2573
1934	240	200	1800	4700	1300	1100	1420	400	200	100	80	70	967
1935	500	3350	6650	6000	3800	3800	3900	1530	545	180	110	95	2538
1936	250	400	1200	14100	5280	2820	2640	1680	645	190	110	100	2451
1937	160	110	200	700	5050	5520	7840	2370	1690	325	120	105	2016
1938	400	4700	4800	6780	12100	11700	5100	2200	695	210	120	110	4076
1939	210	1050	2200	2600	6950	7050	1900	740	330	150	90	85	1946
1940	240	140	1300	2550	10200	5650	2250	740	220	100	80	115	1965
1941	260	100	4200	4650	2550	1000	1180	920	570	210	100	140	1323
1942	230	1530	8950	4591	5472	1721	1056	3391	1408	394	137	98	2415
1943	126	6194	14930	11840	7362	2498	3229	1334	1642	328	160	117	4136
1944	515	1591	836	1932	3504	3148	2919	1191	548	198	103	72	1369
1945	103	645	657	2831	7421	5454	4040	3441	1042	235	119	107	2139
1946	133	4276	9156	8115	5411	4932	2000	1284	563	170	83	93	3013
1947	239	3299	3497	2724	5248	3920	3587	658	993	507	253	173	2066
1948	1438	3881	3160	10320	6289	5410	4955	3056	1740	458	212	181	3418
1949	247	1091	6512	1729	8009	4756	2974	2500	546	183	106	105	2364
1950	292	468	1748	9079	7409	7313	3302	2144	1257	287	122	98	2772
1951	6045	7945	7723	11930	7967	5505	1938	1457	373	146	83	78	4258
1952	1155	3132	11880	7113	9216	6288	4134	2015	982	508	144	132	3882
1953	119	190	3848	14130	9037	4521	2255	4037	3312	576	250	179	3515
1954	360	5522	8401	13530	10080	3049	3780	993	790	266	157	207	3892
1955	201	474	1929	3438	2994	4735	5399	2951	1009	287	104	128	1965
1956	278	3068	19540	16010	7673	7962	4376	3080	1426	369	168	143	5362
1957	1187	1671	5460	2580	8104	10170	3489	1565	536	215	121	126	2909
1958	573	2072	8729	9646	15370	4596	5199	1567	1660	366	158	146	4102
Mean	552	1999	5017	6421	6470	4869	3337	1853	977	266	126	114	2667

Table 393. Observed Mean Discharge, in CFS, N.Umpqua River below Lemole Lake nr Toketee Fls,Ore.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										385	335	325	
1929	339	337	317	332	322	333	350	459	440	335	293	273	344
1930	289	286	360	336	442	390	373	382	338	301	287	276	338
1931	276	305	309	271	284	303	359	362	288	270	259	255	295
1932	237	223	235	288	293	323	357	592	537	375	336	302	341
1933	310	315	314	351	342	336	369	468	830	480	391	373	406
1934	357	352	363	394	384	401	390	350	317	298	291	285	348
1935	298	292	337	356	327	316	373	572	518	372	337	317	368
1936	304	300	297	337	314	342	458	585	463	376	327	320	369
1937	302	287	310	302	330	311	338	472	450	340	306	293	337
1938	312	338	395	396	413	401	451	676	603	440	385	352	430
1939	340	377	369	348	359	374	434	500	396	343	315	307	372
1940	305	301	330	344	340	380	436	407	357	312	291	287	341
1941	283	289	296	314	315	290	289	351	330	295	281	269	300
1942	250	278	326	328	323	294	329	402	401	327	300	284	320
1943	273	348	478	482	387	415	643	750	710	503	422	390	464
1944	395	448	418	393	355	356	386	442	406	354	322	300	381
1945	291	311	306	331	374	351	380	580	461	364	340	329	368
1946	301	311	368	456	413	396	445	715	597	444	390	368	434
1947	382	398	412	368	382	407	482	552	451	408	359	344	412
1948	361	368	349	398	376	372	394	510	713	477	407	382	425
1949	353	366	411	381	390	370	433	776	612	430	393	377	441
1950	396	383	385	399	391	406	433	593	746	505	429	419	457
1951	448	516	587	536	529	504	616	684	589	484	441	422	529
1952	481	455	443	428	423	405	533	845	782	543	462	429	519
1953	405	390	462	515	543	456	474	668	801	603	507	458	523
1954	467	557	537	507	500	482	557	779	590	573	513	451	543
1955	404	401	380	398	388	405	417	316	638	388	319	345	399
1956	382	426	552	640	520	499	520	747	815	602	493	458	555
1957	455	489	571	542	530	551	557	666	561	448	419	412	517
1958	427	412	461	509	523	552	465	701	664	506	501	430	510
Mean	347	359	388	399	393	391	435	563	548	418	371	350	414

Table 394. Observed Mean Discharge, in CFS, Umpqua River near Elkton, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1310	1000	966	
1929	1050	1460	3090	6300	7070	8070	13000	4970	3630	1320	892	800	4270
1930	857	832	10800	7140	17200	5200	3100	3810	2240	1040	817	830	4420
1931	929	2240	2560	4870	3340	8780	9270	2070	1420	970	703	740	3150
1932	1290	4790	10400	14800	10400	22100	10000	8040	4700	1670	1070	912	7530
1933	1080	3530	10100	16600	13300	13100	10200	10500	8240	2390	1250	1150	7590
1934	1089	1253	6469	12320	3731	3770	4709	1934	1479	966	812	778	3287
1935	1928	10280	17910	15000	9981	10670	11380	5932	2820	1407	1037	928	7432
1936	1124	2008	4735	30750	13120	8358	8124	6380	3156	1443	1029	967	6766
1937	864	868	1375	2201	12650	14550	20480	8151	6564	2015	1122	1001	5918
1938	1634	13270	13930	16600	28450	26450	14220	7705	3318	1506	1079	1018	10650
1939	1013	4259	7496	7394	16650	17630	6052	3149	2035	1232	901	892	5662
1940	1115	954	5063	7254	23600	14830	7104	3152	1553	982	816	1053	5558
1941	1188	4125	12520	12140	6916	3462	3964	3868	2901	1531	974	1216	4564
1942	1072	5694	22530	11560	12670	5315	3562	8898	4666	1847	1074	883	6630
1943	903	16300	37080	29330	16950	7196	10450	5098	6669	2267	1428	1192	11220
1944	2494	5418	3063	5805	9600	8098	8704	4218	2397	1279	963	901	4384
1945	877	2070	2160	7907	18380	14270	12260	9503	3478	1404	1015	983	6107
1946	966	12220	23050	21020	12620	15170	6301	5186	3310	1631	1139	1072	8640
1947	1592	11540	10900	6889	12360	10790	11000	2971	3810	1953	1602	1231	6332
1948	3602	9988	7556	24120	16280	13540	11630	8661	5681	2398	1520	1464	8847
1949	1524	4332	19220	5002	20680	12186	7960	9455	3192	1588	1194	1179	7217
1950	1648	2720	5924	22740	18760	20200	9484	7460	5591	2206	1374	1218	8229
1951	14200	18380	19210	27720	20220	13900	6588	5878	2471	1582	1143	1095	11000
1952	4066	8044	25370	15330	20220	13780	11490	6946	4676	2906	1433	1283	9606
1953	1149	1351	8520	32430	22870	11550	6595	11100	9526	2855	1793	1529	9210
1954	1803	15340	22260	27460	21160	8097	10370	4416	3660	1991	1644	1548	9912
1955	1481	1914	5407	10210	8303	11950	14390	9246	4855	2056	1227	1211	6007
1956	2005	10550	46450	34900	16370	17520	11670	9692	5300	2338	1489	1287	13350
1957	4135	5687	16010	5903	16460	22000	9082	5006	2652	1484	1238	1218	7532
1958	2239	5052	22130	20960	31240	9189	10840	4923	5282	2013	1325	1210	9568
Mean	2031	6216	13443	15421	15385	12390	8963	6277	4042	1742	1132	1093	7353

Table 395. Observed Mean Discharge, in CFS, South Fork Coquille River at Powers, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										37	17	19	
1929	22	300	1280	1130	1050	718	1370	212	234	66	33	21	536
1930	21	19	1530	800	1270	532	240	375	174	51	28	31	419
1931	35	288	323	1290	481	1370	712	101	66	33	19	24	396
1932	239	954	2010	1810	1130	1660	1010	425	101	44	24	16	786
1933	33	606	1420	2040	1610	2240	951	1520	489	81	37	52	922
1934	64	77	2181	1421	422	330	381	204	93	43	25	23	442
1935	307	1821	1579	1805	1110	1397	1170	263	88	46	26	20	800
1936	73	420	875	4201	1539	734	745	338	158	64	33	22	767
1937	17	16	141	323	1213	794	1990	977	699	154	50	36	527
1938	89	3248	1876	1693	3276	3818	1306	458	85	35	24	20	1313
1939	37	521	841	983	1562	1597	236	78	64	33	17	16	493
1940	41	30	1526	1541	2973	1522	640	420	84	39	21	44	734
1941	188	728	2343	1952	861	437	700	508	154	73	37	65	672
1942	52	1003	3187	1576	1906	616	394	743	308	103	45	30	826
1943	33	2000	3540	2413	1102	722	1030	290	324	101	46	28	969
1944	410	830	479	881	1111	934	712	278	273	72	37	25	501
1945	36	758	559	1064	2381	2054	1353	573	181	58	33	31	745
1946	39	2214	3053	1976	1560	1451	462	166	90	46	25	21	922
1947	126	1926	816	640	1298	1184	780	107	406	186	101	49	628
1948	1129	1098	899	2337	1613	1179	1747	829	199	87	51	46	933
1949	77	715	1929	481	2118	1366	387	654	93	44	25	24	651
1950	70	409	1094	2818	2098	2020	720	444	129	53	27	22	820
1951	1945	1927	1820	3047	1743	1288	462	429	107	44	24	22	1071
1952	741	1417	2612	1878	2005	1331	882	312	135	93	32	22	953
1953	18	52	1777	4160	1628	1237	755	1568	412	105	68	43	987
1954	213	2107	2234	3537	2053	960	946	134	154	68	48	57	1037
1955	135	676	1384	1258	820	1373	1383	604	138	62	30	34	658
1956	251	1563	4599	4200	1576	1627	980	387	121	53	27	28	1289
1957	570	533	1037	800	2209	1835	810	446	147	58	35	47	702
1958	328	664	2463	2443	4151	1079	1244	206	105	57	30	28	1047
Mean	245	964	1714	1883	1662	1313	883	468	194	68	35	32	785

Table 396. Observed Mean Discharge, in CFS, Coquille River at Coquille, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										147	67	75	
1929	87	1191	5082	4486	4169	2850	5439	842	929	262	131	83	2129
1930	83	75	6074	3176	5042	2112	953	1489	691	202	111	123	1678
1931	139	1143	1282	5121	1910	5439	2827	401	262	131	75	95	1569
1932	949	3787	7980	7186	4486	6590	4010	1687	401	175	95	64	3118
1933	131	2406	5637	8099	6392	8893	3775	6034	1941	322	147	206	3665
1934	254	306	8659	5641	1675	1310	1513	810	369	171	99	91	1742
1935	1219	7229	6269	7166	4407	5546	4645	1044	349	183	103	79	3178
1936	290	1667	3474	16678	6110	2914	2958	1342	627	254	131	87	3044
1937	67	64	560	1283	4816	3152	7900	3879	2775	611	199	143	2121
1938	353	12895	7448	6721	13006	15157	5185	1818	337	139	95	79	5267
1939	147	2068	3339	3903	6201	6340	937	310	254	131	67	64	1980
1940	163	119	6058	6118	11803	6042	2541	1667	333	155	83	175	2938
1941	746	2890	9302	7749	3418	1735	2779	2017	611	290	147	258	2662
1942	206	3982	12652	6257	7567	2446	1564	2950	1223	409	179	119	3296
1943	131	7940	14054	9580	4375	2866	4089	1151	1286	401	183	111	3847
1944	1628	3295	1902	3498	4411	3708	2827	1104	1084	286	147	99	1999
1945	143	3009	2219	4224	9453	8154	5371	2275	719	230	131	123	3004
1946	155	8790	12120	7845	6193	5760	1834	659	357	183	99	83	3673
1947	500	7646	3240	2541	5153	4700	3097	425	1612	738	401	195	2521
1948	4482	4359	3569	9278	6404	4681	6936	3291	790	345	202	183	3710
1949	306	2839	7658	1910	8408	5423	1536	2596	369	175	99	95	2618
1950	278	1624	4343	11187	8329	8019	2858	1763	512	210	107	87	3276
1951	7722	7650	7225	12097	6920	5113	1834	1703	425	175	95	87	4254
1952	2942	5625	10370	7456	7960	5284	3502	1239	536	369	127	87	3791
1953	71	206	7055	16515	6463	4911	2997	6225	1636	417	270	171	3911
1954	846	8365	8869	14042	8150	3811	3756	532	611	270	191	226	4139
1955	536	2684	5494	4994	3255	5451	5491	2398	548	246	119	135	2613
1956	996	6205	18258	16674	6257	6459	3891	1536	480	210	107	111	5099
1957	2263	2116	4117	3176	8770	7285	3616	1771	584	230	139	187	2855
1958	1302	2636	9778	9699	16479	4284	4939	818	417	226	119	111	4234
Mean	971	3827	6739	7510	6599	5214	3520	1859	769	272	140	125	3129

Table 397. Observed Mean Discharge, in CFS, Rogue River at Dodge Bridge, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1290	1120	1090	
1929	1060	1000	1330	1580	1460	2190	2800	2933	1964	1031	843	804	1583
1930	750	730	2880	1990	3800	1910	1510	1573	1058	760	680	738	1532
1931	600	820	900	900	908	1700	2011	1138	818	664	571	612	970
1932	640	1080	1380	2180	1980	4850	3520	4862	3173	1387	987	879	2243
1933	860	1460	1900	2210	2300	3250	3600	4409	4853	1804	1138	1102	2407
1934	1020	1080	1333	2800	1600	1850	1760	1191	954	758	697	704	1312
1935	910	2370	3590	2950	3100	2480	3800	3748	2209	1227	934	883	2350
1936	940	1000	1395	5203	3050	2850	3610	3364	2155	1227	996	968	2230
1937	840	870	1001	790	1990	2900	5005	4572	3360	1397	991	965	2057
1938	1100	3060	1750	4000	5657	5905	3080	5193	2835	1461	1147	1114	3026
1939	1176	1509	2490	1942	2735	4339	3584	2600	1709	1235	1009	983	2106
1940	1106	1012	1765	2272	4508	4372	3127	1931	1230	974	888	987	2001
1941	1046	1502	2252	2878	2532	1784	1787	2238	1553	1090	899	970	1075
1942	963	1291	4191	3162	3296	1878	2040	2994	2271	1234	977	901	2095
1943	934	3958	7591	6701	4843	3450	4147	3204	3356	1843	1438	1327	3560
1944	1498	1874	1543	1924	2456	2511	2928	2680	1883	1199	1014	924	1866
1945	977	1200	1195	2182	4761	2977	3181	4720	2393	1340	1103	1055	2240
1946	1115	2352	4952	4695	3128	4058	3468	3882	2770	1623	1232	1180	2874
1947	1246	2325	2786	1961	2989	2966	3154	2116	1891	1252	1078	1049	2060
1948	1373	1960	1838	5258	3258	3023	3818	3892	3759	1816	1298	1210	2706
1949	1276	1552	2985	1512	3084	3650	4139	4718	2575	1434	1165	1093	2428
1950	1236	1319	1366	3333	3693	4965	4032	4132	3444	1736	1290	1195	2638
1951	3099	3931	6395	5799	6183	3488	3940	3475	2154	1531	1336	1264	3536
1952	1920	2624	5063	3263	5661	3955	5220	4945	3810	2312	1574	1420	3471
1953	1335	1361	1999	6828	6454	3200	3108	4327	4534	2431	1711	1481	3211
1954	1553	4211	5232	5665	5656	3230	4166	3296	2581	1656	1412	1382	3320
1955	1314	1336	1477	1748	1798	2285	2848	3482	2948	1431	1079	1046	1899
1956	1197	2271	8673	7958	4228	4311	4659	5287	3825	2140	1656	1495	3984
1957	2040	2310	4519	2321	4671	7151	4344	3384	2217	1540	1365	1333	3093
1958	1550	2114	3970	5418	8382	3611	3774	4049	3377	1916	1515	1391	3390
Mean	1222	1849	2991	3381	3672	3370	3372	3478	2587	1448	1134	1082	2465

Table 398. Observed Mean Discharge in CFS, Rogue River at Grants Pass, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										930	620	600	
1929	1228	1131	1612	2030	1885	2777	3348	3809	2468	1032	790	799	1843
1930	995	931	3740	2597	5623	2393	1616	1927	1214	761	648	735	1932
1931	905	1004	1096	1256	1268	2083	2231	1324	882	665	553	602	1156
1932	889	1190	2019	2880	2597	7514	4534	6478	4141	1388	916	873	2952
1933	1080	1503	2326	2941	3076	4526	4659	5850	6466	1807	1049	1092	3031
1934	1217	1196	1754	3862	2096	2281	1898	1398	1070	759	663	701	1575
1935	1123	2381	4996	4120	4333	3205	4974	4937	2806	1228	1126	877	3009
1936	1134	1152	1657	8329	4285	3826	4682	4406	2732	997	924	960	2924
1937	1058	1025	1230	1148	2587	3904	7155	6077	4399	1399	920	958	2655
1938	1267	3086	5160	5995	9169	9648	7257	6935	3672	1463	1056	1104	4651
1939	1320	2010	3260	2402	4011	5776	3808	2667	1603	1102	869	888	2468
1940	1209	1132	2297	3139	7517	6720	4158	1973	1131	817	820	970	2639
1941	1184	1807	3137	4150	3680	2118	2174	2630	1851	1015	898	1134	2140
1942	1180	1633	6796	4627	5206	2545	2392	3921	2631	1120	805	823	2797
1943	987	5178	11480	11500	7079	4409	5108	3478	3632	1742	1326	1258	4757
1944	1693	2163	1811	2416	3165	3281	3580	2824	1872	1107	944	899	2141
1945	1159	1478	1450	2591	6679	4015	3784	5578	2500	1124	940	945	2660
1946	1143	3173	7041	7057	4522	5668	3978	3953	2593	1434	1055	1067	3558
1947	1404	2840	3306	2482	3873	3862	3802	1974	2006	1175	983	939	2375
1948	1616	2339	2265	8340	4339	4382	5407	5126	4295	1719	1160	1152	3510
1949	1448	1914	4283	1995	4904	4924	4952	5180	2636	1293	1028	1045	2955
1950	1466	1554	1678	5277	5334	7073	5443	4667	3712	1595	1094	1088	3320
1951	4934	5872	10240	9823	9766	5151	4438	3661	2000	1312	1128	1103	4931
1952	2071	2982	7735	5596	9787	6214	6924	5687	4008	2206	1480	1425	4658
1953	1455	1593	3063	11420	9347	4450	3905	5739	5647	2335	1629	1561	4318
1954	1812	5626	7351	11140	9392	4569	5392	3502	2802	1551	1385	1420	4632
1955	1564	1629	1911	2356	2469	2984	3758	3996	3115	1370	971	1018	2259
1956	1405	3182	15170	14360	8337	7189	6015	6360	4108	1966	1552	1482	5938
1957	2713	2916	6265	3308	6995	11410	5849	3700	2039	1349	1185	1289	4072
1958	1798	2788	6391	10040	14600	5545	5476	4487	4063	1924	1315	1450	4928
Mean	1482	2280	4417	5306	5597	4814	4425	4141	2936	1358	1040	1014	3235

AD-A036 573 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

UNCLASSIFIED NL

4 OF 6
AD
A036573

Table 399. Observed Mean Discharge, in CFS, Illinois River nr Kerby, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										72	34	35	
1929	57	791	1700	1320	1100	797	2110	650	357	59	32	29	746
1930	36	40	3470	1210	2870	1080	575	439	147	42	31	35	820
1931	43	676	486	1860	703	1820	941	199	98	40	16	17	576
1932	189	1220	2070	2020	1140	2570	1480	1150	463	97	33	24	1040
1933	40	1130	1820	2000	1940	2770	1510	2140	1270	270	74	60	1250
1934	96	118	2016	2423	779	711	455	230	98	38	20	17	586
1935	450	2191	1631	2317	2039	1765	2148	889	293	83	36	30	1149
1936	120	311	1261	5533	1917	1209	1028	831	389	97	40	35	1066
1937	33	41	183	293	1828	2109	3753	1329	776	173	55	39	874
1938	97	2980	2317	2135	4527	5499	2359	1713	706	141	42	35	1861
1939	69	528	1138	956	1615	2108	738	273	132	46	22	21	632
1940	30	48	1926	2650	4931	3028	1271	575	156	49	25	50	1217
1941	194	772	3291	3780	2197	1205	1479	1129	353	134	58	70	1220
1942	66	547	4138	2459	2938	829	799	1536	659	139	50	35	1176
1943	48	2878	5681	4434	2026	1354	1564	632	518	122	54	38	1613
1944	366	890	707	1411	932	1094	876	603	390	97	45	33	619
1945	44	1195	1047	1520	4016	2024	1526	1103	367	82	34	32	1062
1946	63	2751	4307	3042	2202	2163	1114	735	327	93	41	31	1403
1947	115	2002	1082	747	1735	2166	1201	252	392	211	127	68	833
1948	1100	648	573	4303	2244	1518	2980	1830	807	212	92	77	1363
1949	127	730	2318	698	2374	1914	1001	1206	262	72	39	42	891
1950	83	407	687	4199	2738	3443	1448	1038	401	99	47	37	1213
1951	3363	2869	4457	4010	3630	1559	889	740	180	45	22	20	1810
1952	606	1773	4735	3014	4497	1728	1921	1382	524	116	45	25	1689
1953	35	95	2904	7375	2421	1696	1756	2067	1193	296	101	66	1671
1954	282	3041	2145	4820	3618	1929	2159	563	297	84	40	56	1572
1955	92	616	1544	1355	896	1215	1591	1125	362	83	33	35	745
1956	135	1488	7305	7076	3064	2314	1775	1102	470	131	64	45	2088
1957	826	902	1177	1340	3570	4125	1548	1016	232	91	52	56	1232
1958	571	1710	3666	4896	7833	2049	2527	974	484	117	46	42	2039
Mean	313	1180	2393	2840	2611	1993	1551	982	437	112	47	40	1208

Table 400. **Observed** Mean Discharge, in CFS, Rogue River nr Gold Beach, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1591	932	921	
1929	1895	4522	13211	10485	7088	7466	15858	8133	4642	1616	1098	1067	6357
1930	1512	1055	26031	10567	24517	9502	3981	4406	2318	1235	932	1055	7259
1931	1462	3669	5711	12488	3766	14822	7068	2111	1738	1127	713	771	4621
1932	2211	8028	15693	15239	8277	26608	13241	14580	6990	2208	1220	1102	9616
1933	1617	7522	14538	14955	14241	24594	13916	20400	13837	3846	1718	1642	11069
1934	2071	1601	15344	19076	5306	6402	3337	2330	1912	1208	856	870	5027
1935	3777	17267	16419	18208	16696	15330	18375	11330	4839	1968	1454	1155	10568
1936	2092	2206	10717	48482	16109	12177	10736	10000	5036	1809	1285	1280	10161
1937	1544	1153	4026	4175	12780	18577	31507	15724	8799	2751	1413	1334	8649
1938	2142	20617	22051	20326	40816	52354	23167	20272	8417	2749	1474	1468	17987
1939	2062	4135	11764	8821	13073	20975	7489	4105	2651	1603	1081	1090	6561
1940	1691	1315	15339	19483	42020	30168	12041	5624	2370	1341	1057	1449	11134
1941	2566	5197	24359	28391	17530	10148	10937	10579	4181	2107	1434	1796	9926
1942	1904	3760	33895	19742	24825	7538	6404	14315	6456	2268	1271	1168	10281
1943	1593	21764	47501	42833	20195	13764	14745	7515	6562	2745	1825	1626	15213
1944	3973	6242	7670	11226	7287	10272	7927	6547	4135	1914	1354	1204	5806
1945	1729	8151	9272	12168	33914	18216	12865	13239	4857	1872	1255	1248	9862
1946	1820	19331	35039	26745	18270	21304	10493	9174	4787	2263	1429	1369	12669
1947	2379	17264	11633	7914	14095	19447	10603	3223	4272	2658	2077	1546	8076
1948	7771	5095	7393	38167	18084	14636	24440	17934	9082	3366	2004	1879	12487
1949	2524	5024	19745	7637	19747	18437	10760	13425	4375	1970	1387	1435	8857
1950	2285	3078	7390	32942	22836	33050	14243	11761	6285	2446	1518	1429	11591
1951	23993	23355	40089	37133	35560	16130	9462	8473	3381	1823	1341	1305	16806
1952	5634	16448	37994	24862	41576	18765	19746	15929	7512	3331	1916	1699	16257
1953	2002	2002	21715	71969	25348	16362	14711	19995	12387	4658	2598	2209	16301
1954	3736	22563	22220	46924	35141	18954	19650	7520	4908	2361	1789	1999	15604
1955	2441	4096	12639	11036	6342	10701	12945	11436	5349	2108	1275	1343	6807
1956	2451	13892	62844	73102	29516	24799	17678	14674	7397	3183	2188	1936	21150
1957	7444	7255	15166	11751	30920	43155	15375	10567	3709	2148	1664	1809	12566
1958	5255	15907	29674	44625	72846	20987	21796	11957	7373	2992	1790	1890	19695
Mean	3519	9147	20236	25049	22624	19188	13850	10938	5685	2322	1480	1439	11290

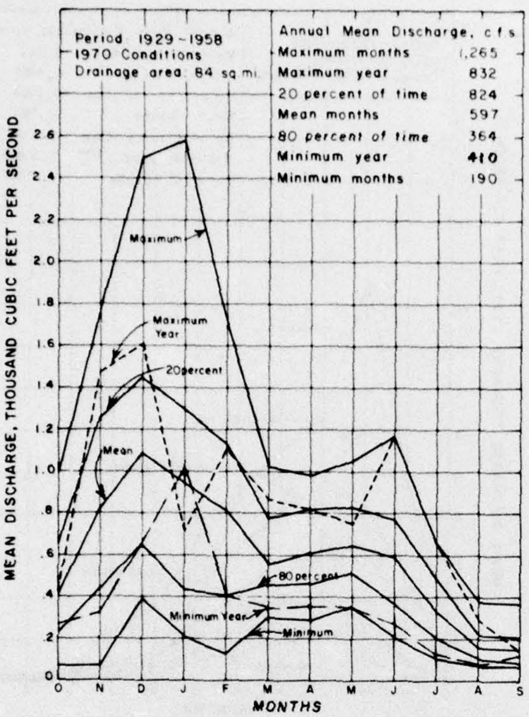


Figure 669 Monthly discharge, Soleduck River near Fairholm, Washington

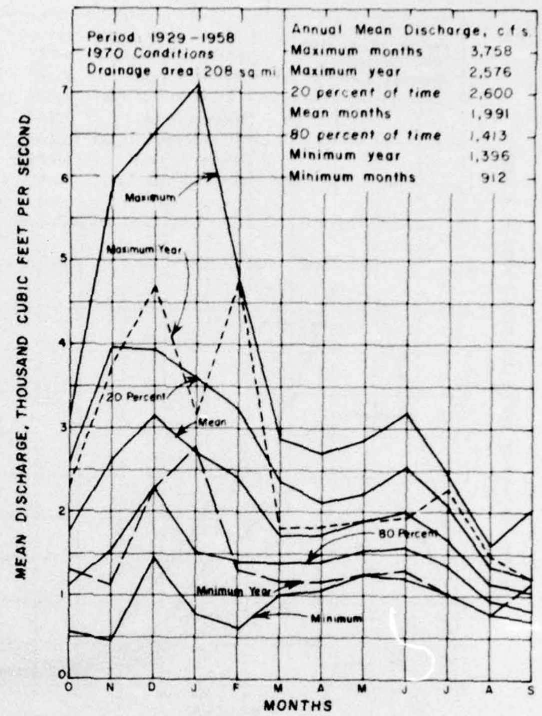


Figure 670 Monthly discharge, Hoh River near Forks, Washington

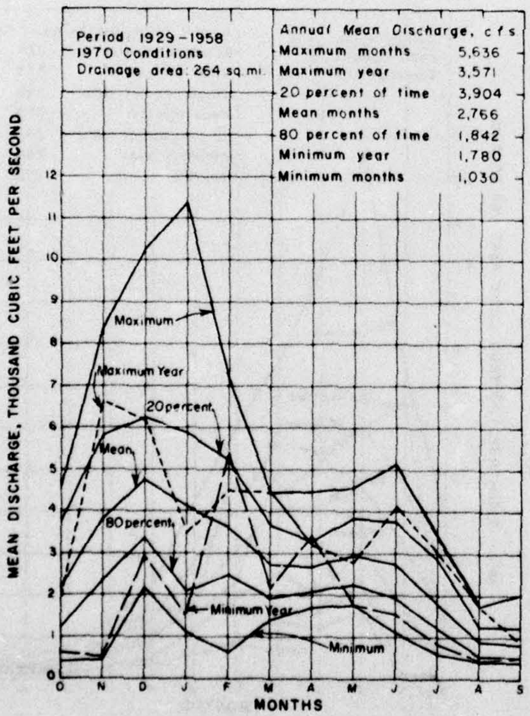


Figure 671 Monthly discharge, Quinault River at Quinault Lake, Washington

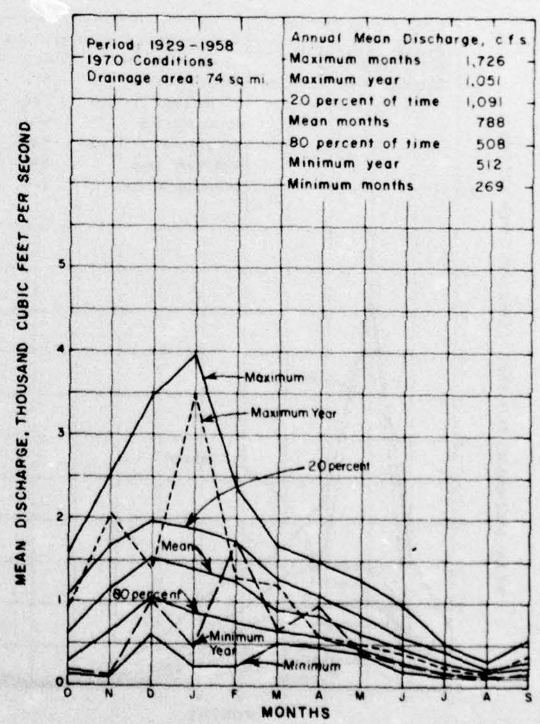


Figure 672 Monthly discharge, Wynoochee River above Save Creek near Aberdeen, Washington

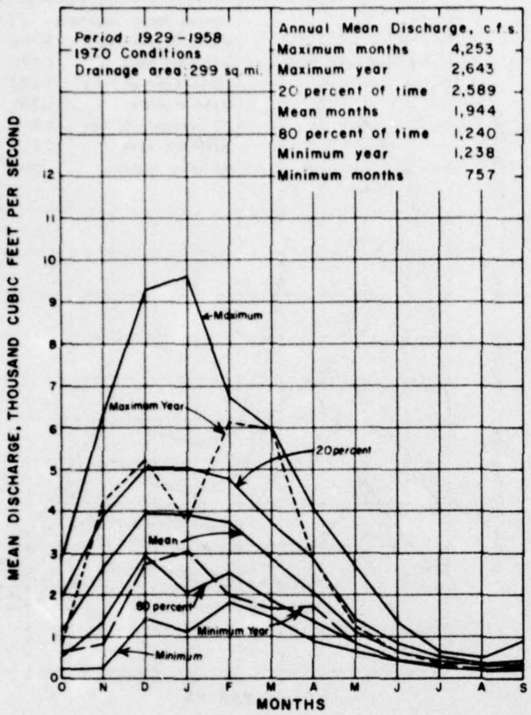


Figure 673 Monthly discharge, Satsop River near Satsop, Washington

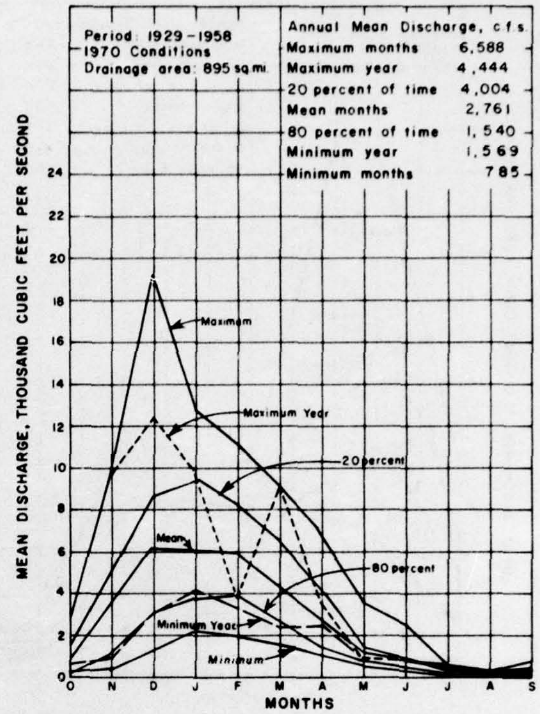


Figure 674 Monthly discharge, Chehalis River near Grand Mound, Washington

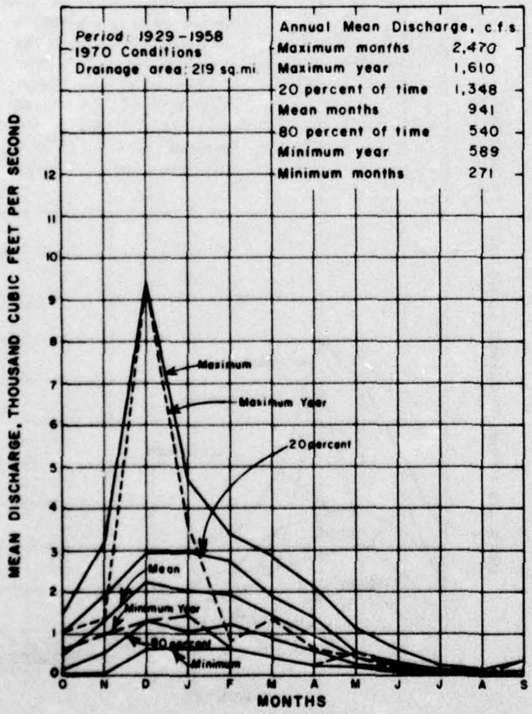


Figure 675 Monthly discharge, North River near Raymond, Washington

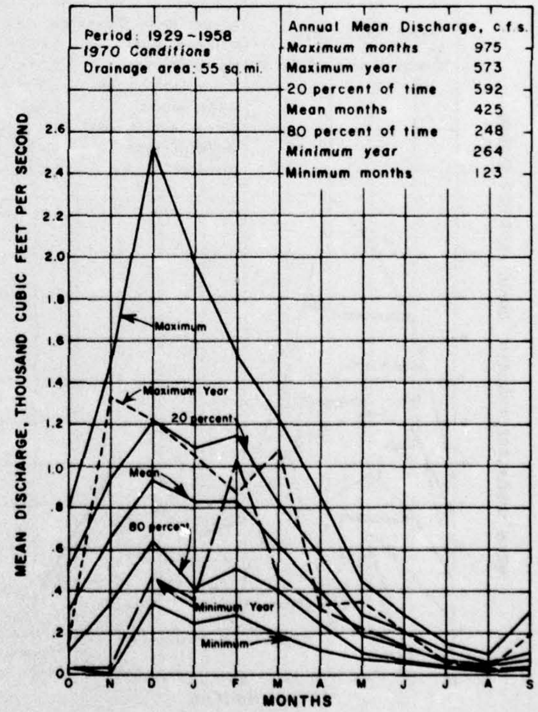


Figure 676 Monthly discharge, Naselle River near Naselle, Washington

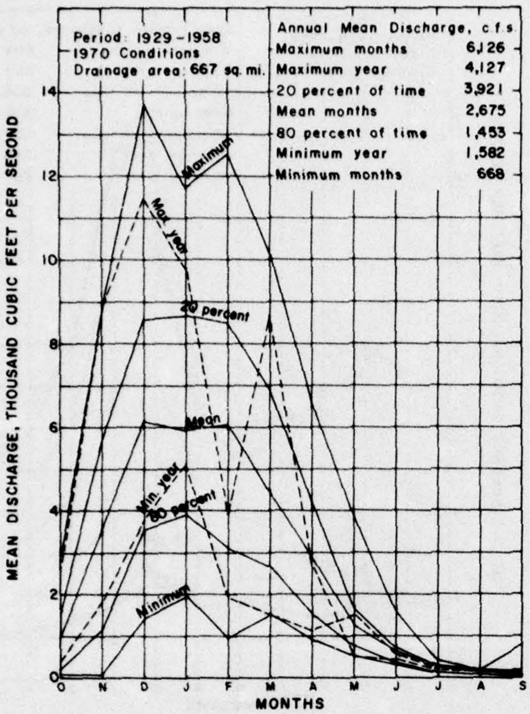


Figure 677 Monthly discharge, Nehalem River near Foss, Oregon

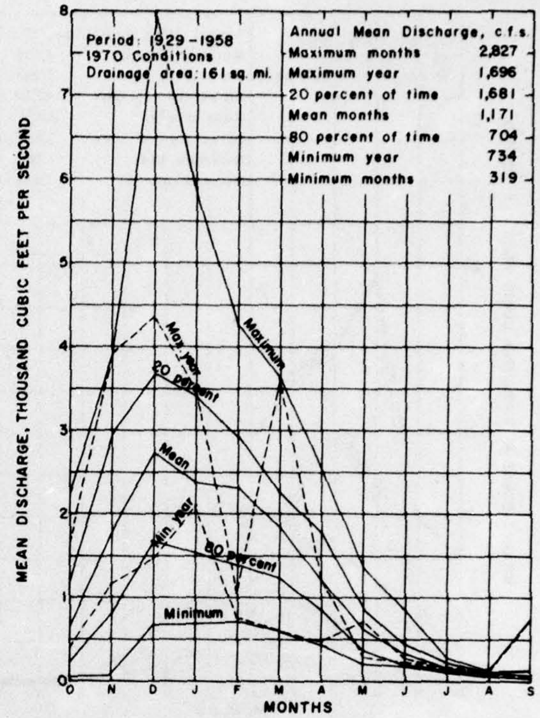


Figure 678 Monthly discharge, Wilson River near Tillamook, Oregon

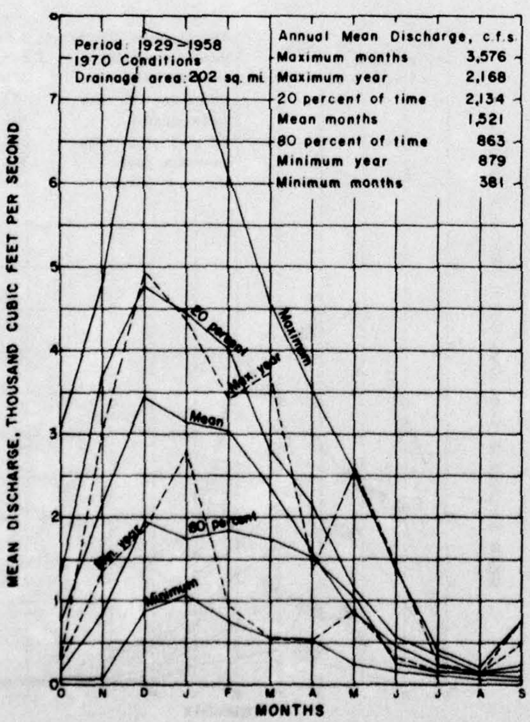


Figure 679 Monthly discharge, Siletz River at Siletz, Oregon

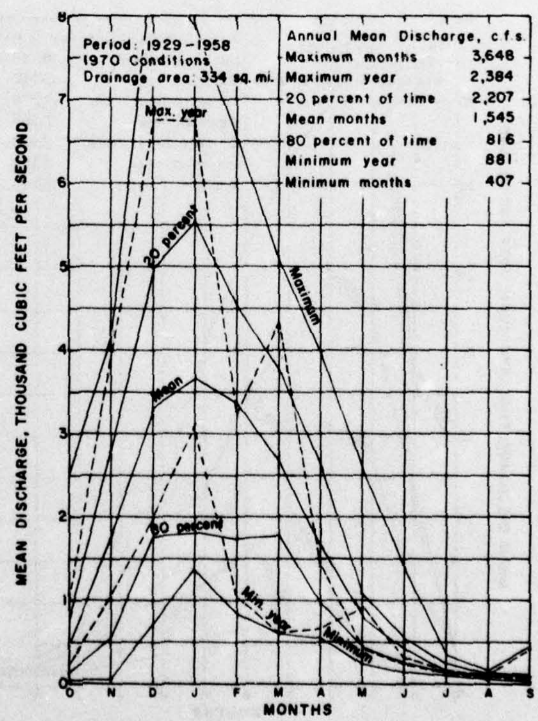


Figure 680 Monthly discharge, Alsea River near Tidewater, Oregon

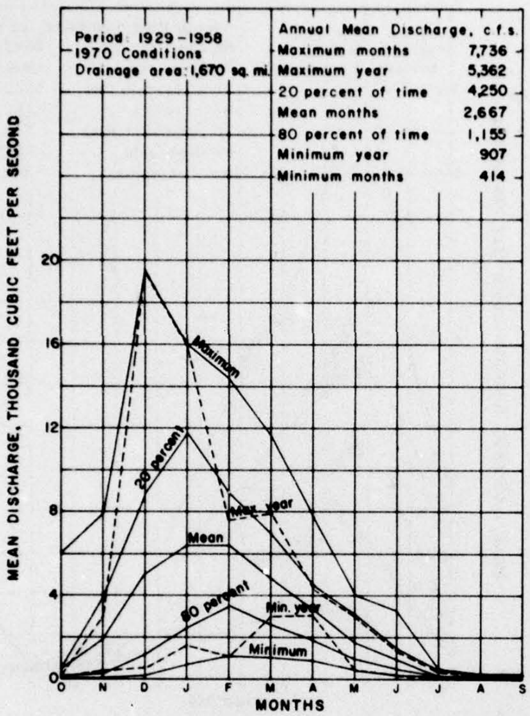


Figure 681 Monthly discharge, South Umpqua River near Brockway, Oregon

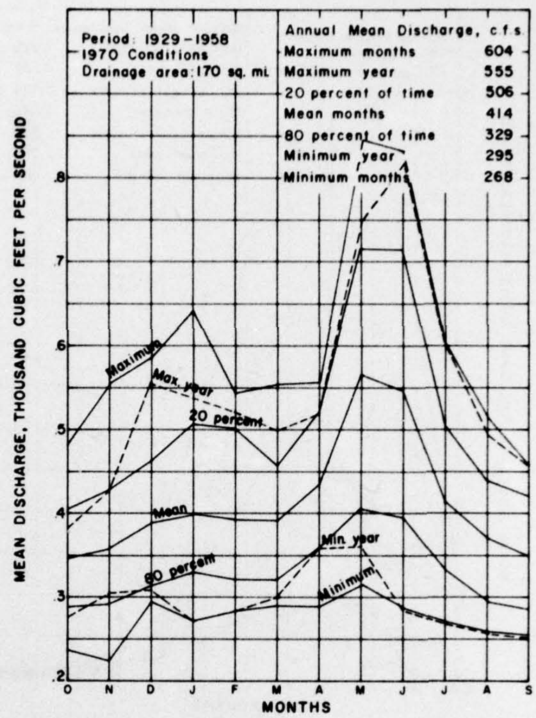


Figure 682 Monthly discharge, North Umpqua River below Lemolo Lake near Toketee Falls, Oregon

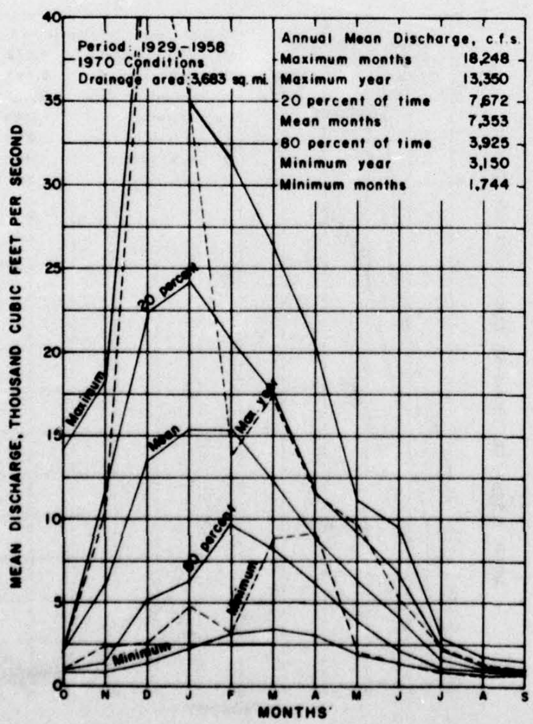


Figure 683 Monthly discharge, Umpqua River near Elkton, Oregon

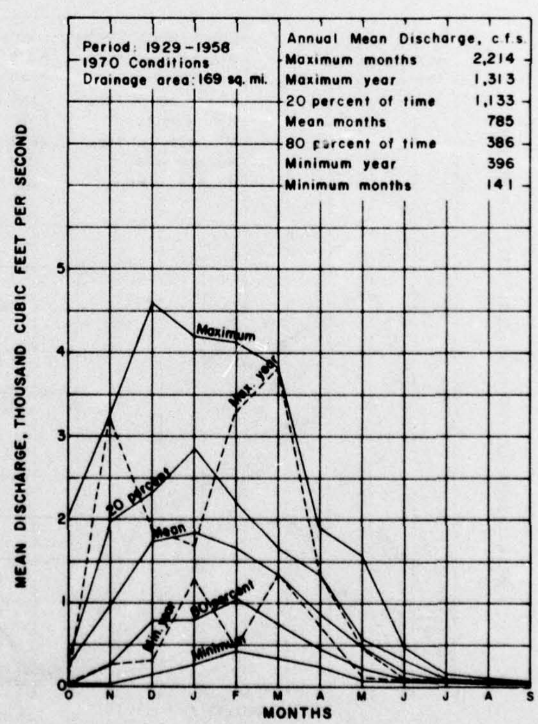


Figure 684 Monthly discharge, South Fork Coquille River at Powers, Oregon

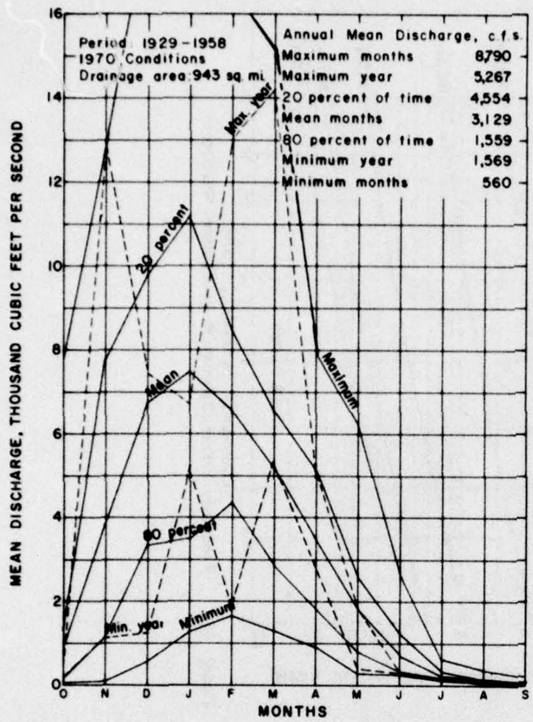


Figure 685 Monthly discharge, Coquille River at Coquille, Oregon

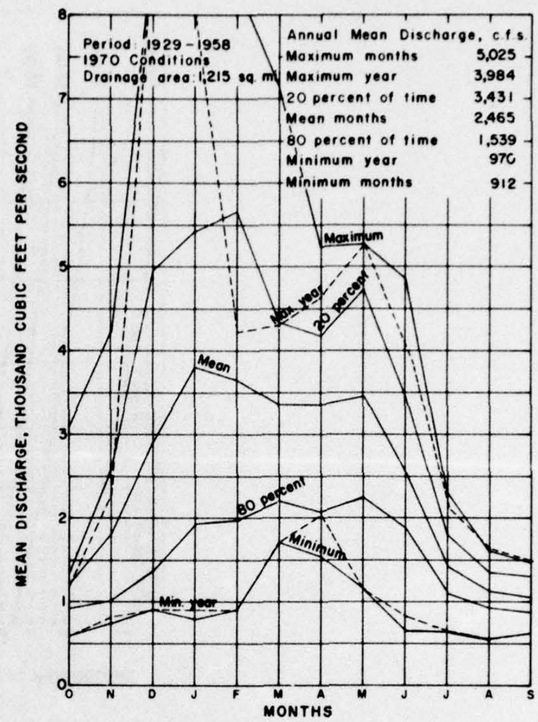


Figure 686 Monthly discharge, Rogue River at Dodge Bridge

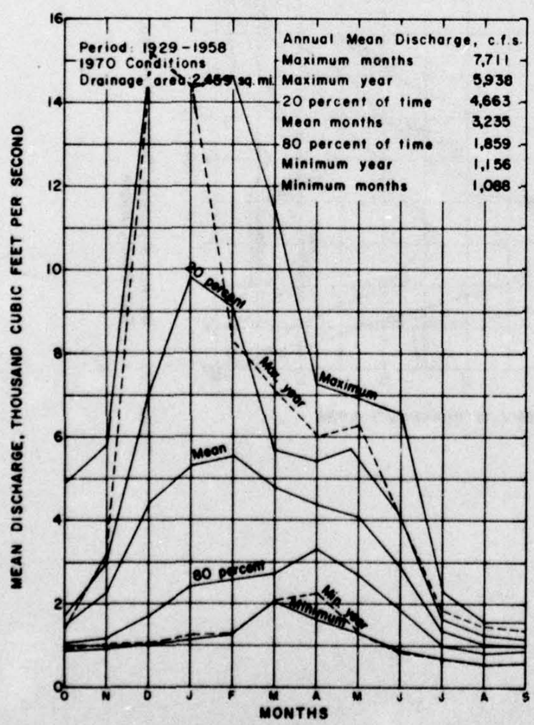


Figure 687 Monthly discharge, Rogue River at Grants Pass, Orego.

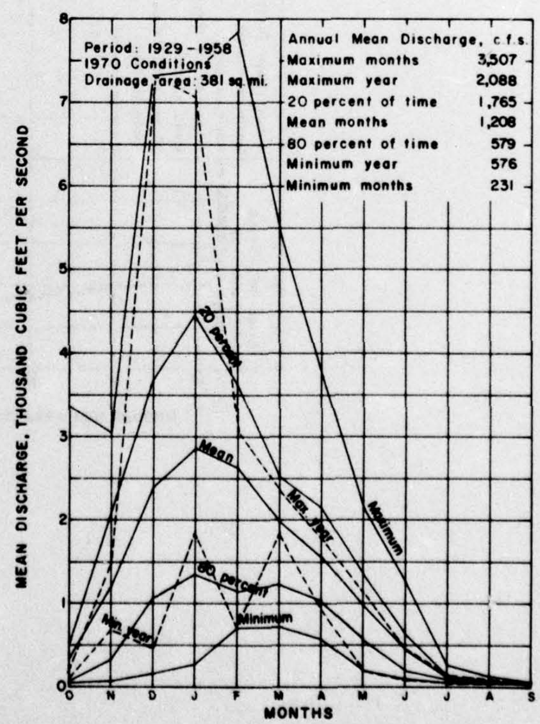


Figure 688 Monthly discharge, Illinois River near Kerby, Oregon

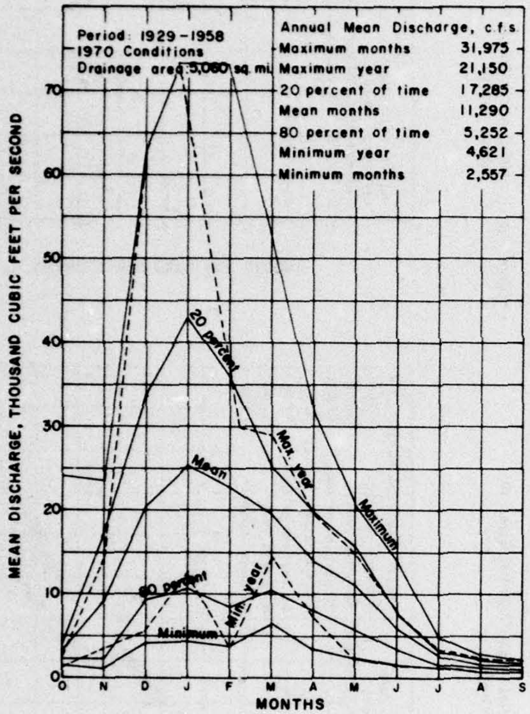


Figure 689 Monthly discharge, Rogue River near Gold Beach, Oregon

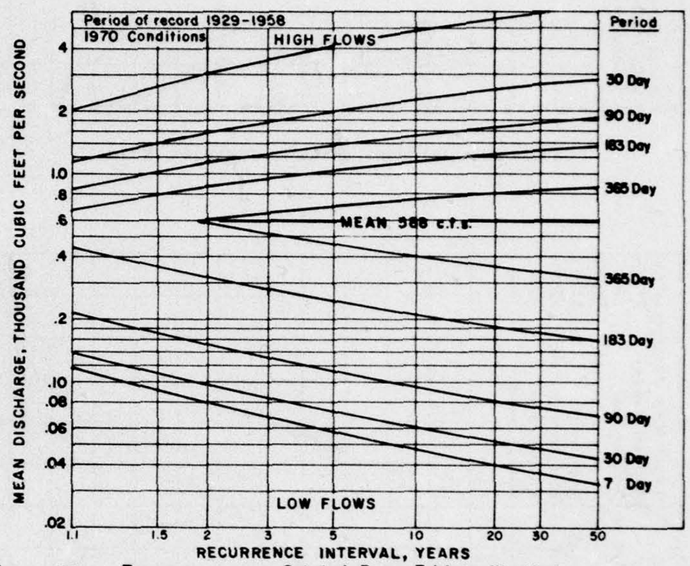


Figure 690 Frequency curves, Soleduck R. nr. Fairholm, Washington

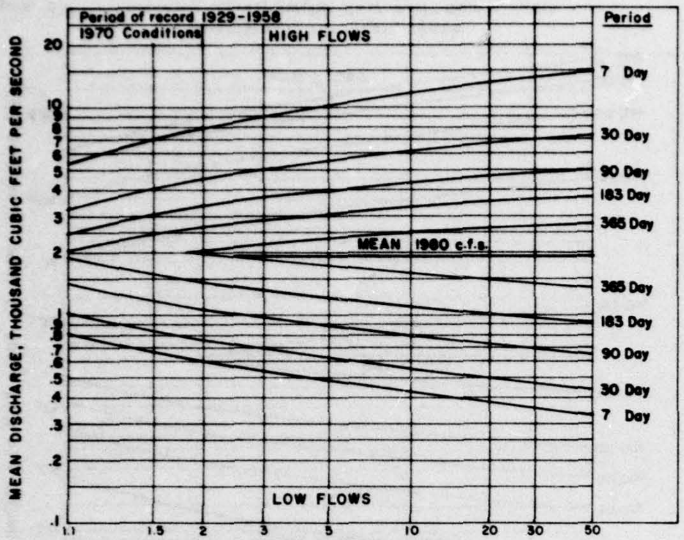


Figure 691 Frequency curves, Hoh River near Forks, Washington

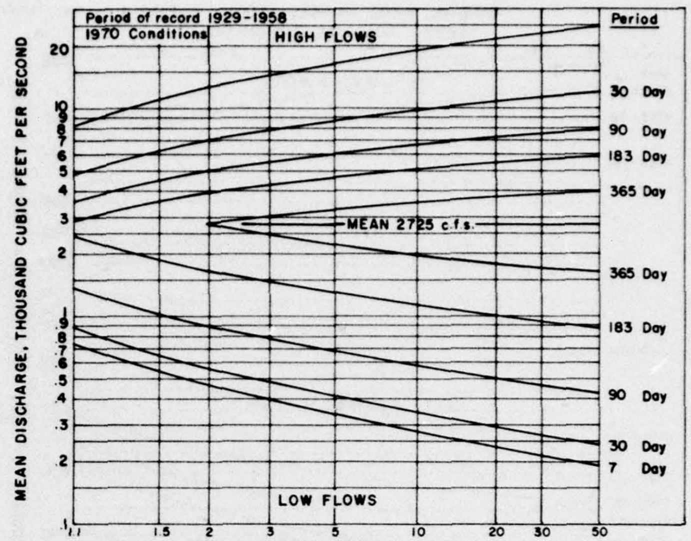


Figure 692 Frequency curves, Quinault R. at Quinault Lake, Washington

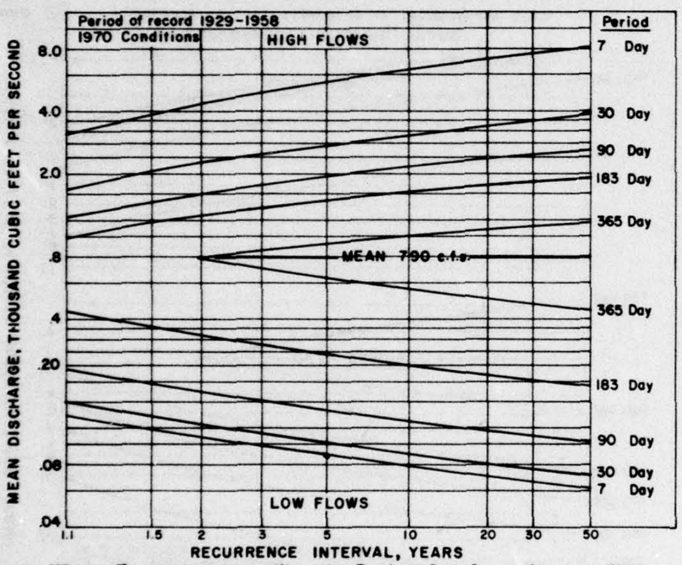


Figure 693 Frequency curves, Wynoochee R. above Save Cr., nr. Aberdeen, Wash.

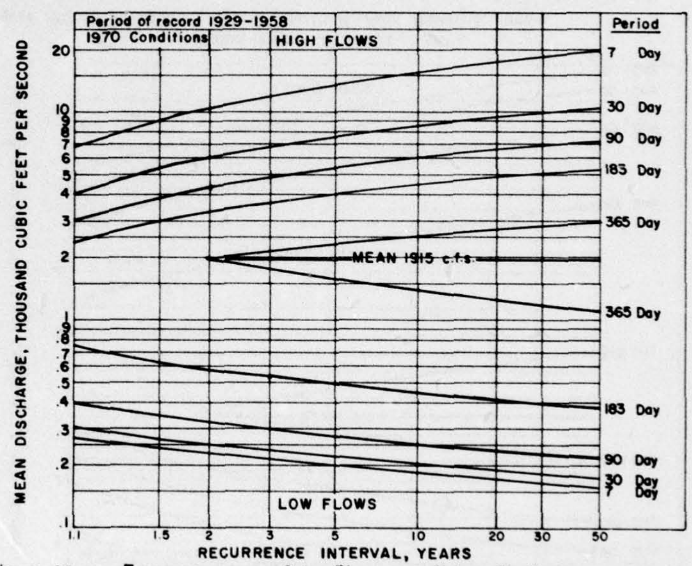


Figure 694 Frequency curves, Satsop River near Satsop, Washington

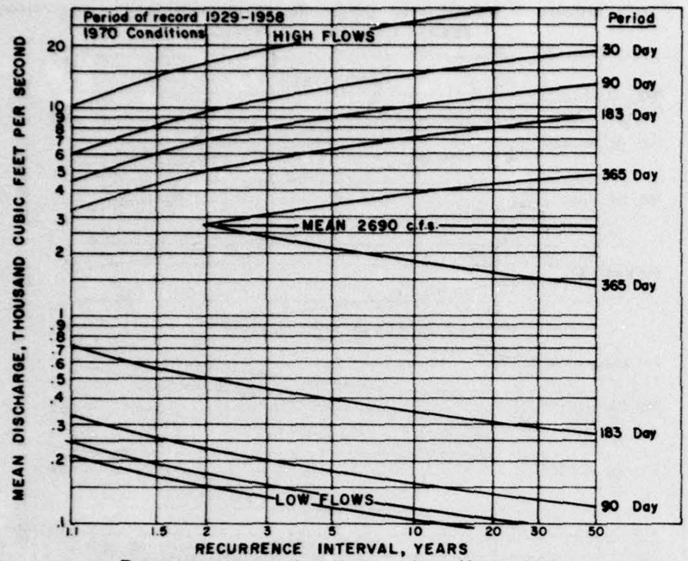


Figure 695 Frequency curves, Chehalis R. nr. Grand Mound, Wash.

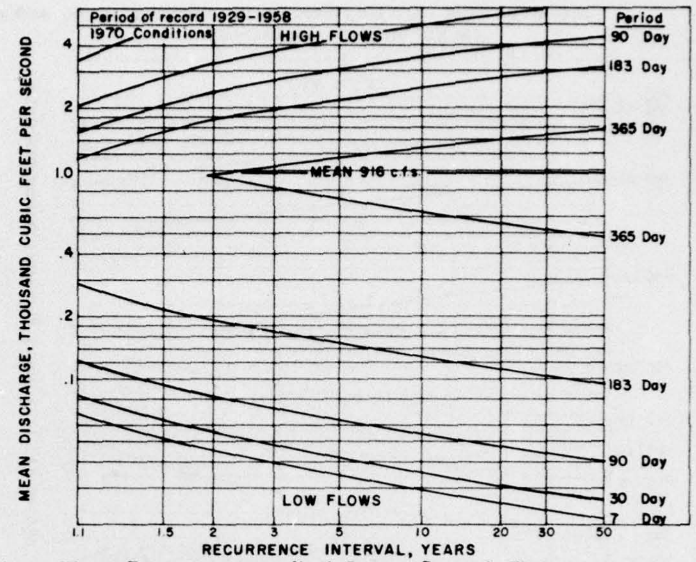


Figure 696 Frequency curves, North R. near Raymond, Wash.

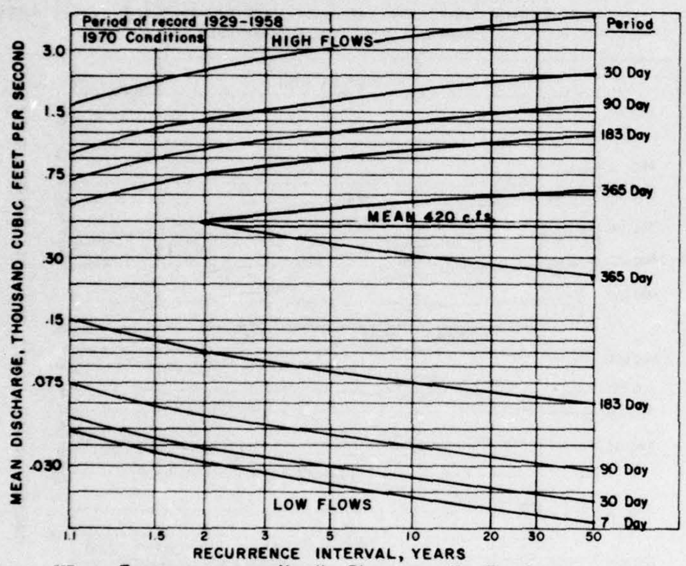


Figure 697 Frequency curves, Naselle River near Naselle, Wash.

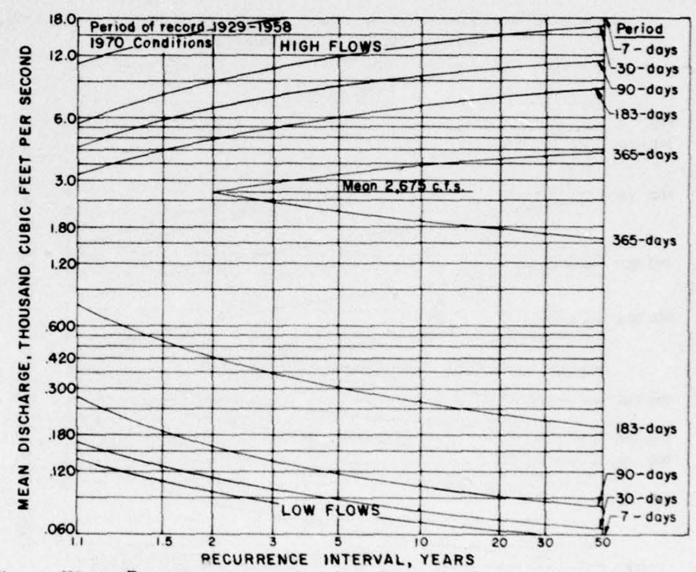


Figure 698 Frequency curves, Nehalem River Nr. Foss

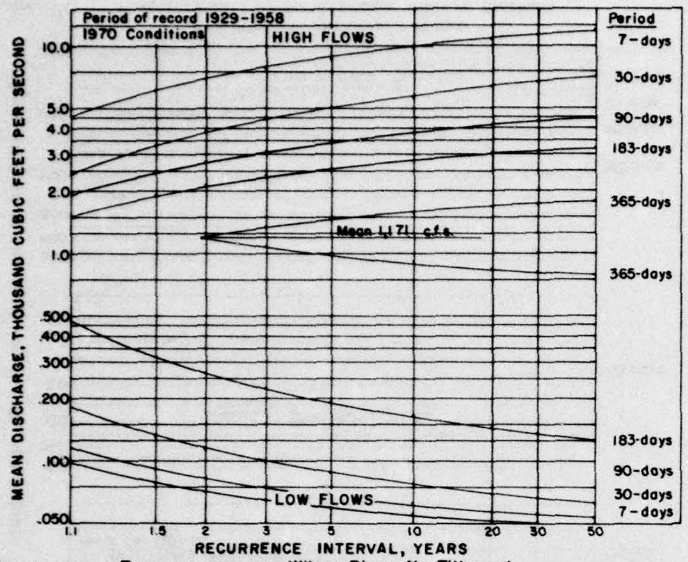


Figure 699 Frequency curves, Wilson River Nr. Tillamook

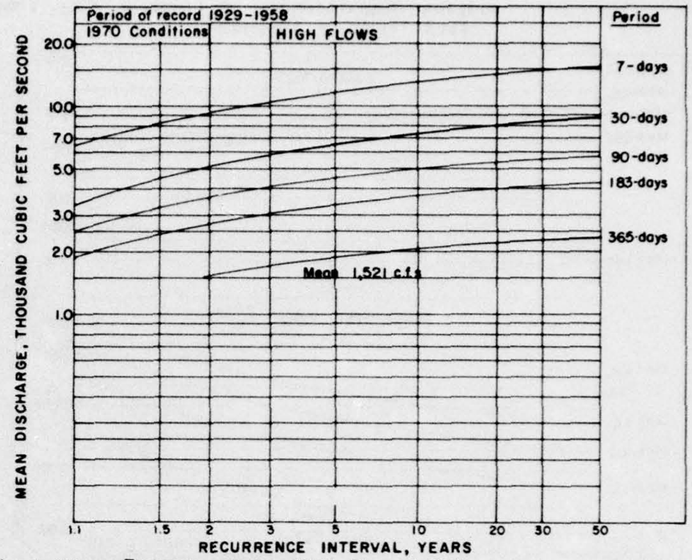


Figure 700 Frequency curves, Siletz River at Siletz

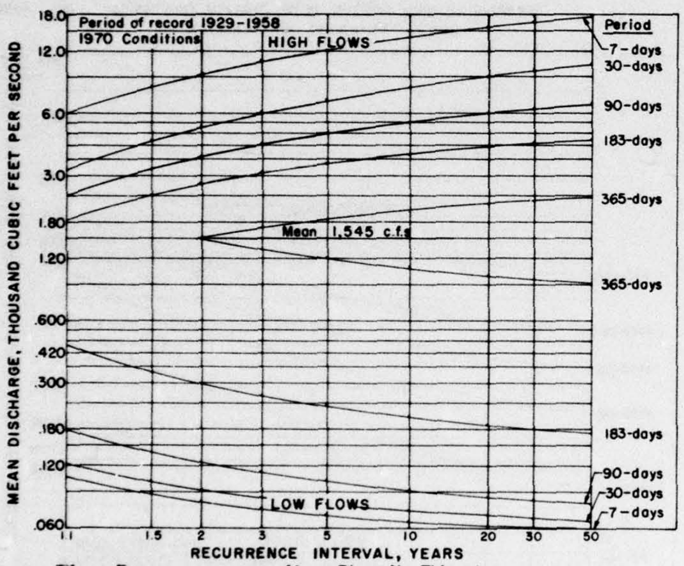


Figure 701 Frequency curves, Alsea River Nr. Tidewater

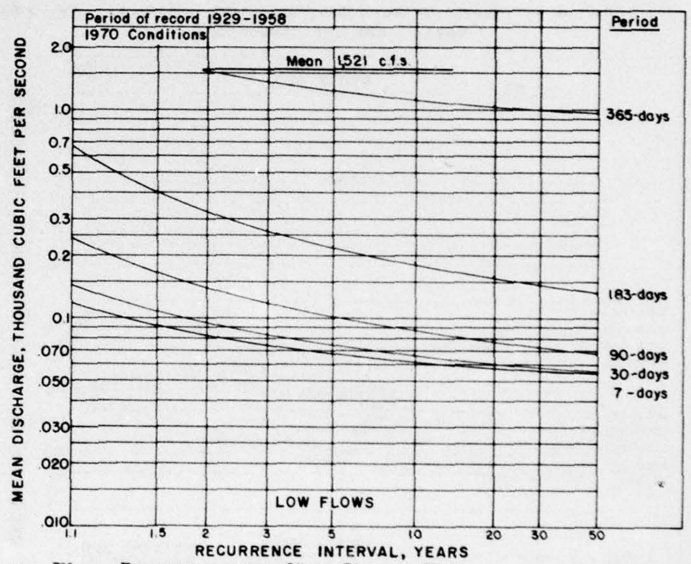


Figure 700 Frequency curves, Siletz River at Siletz

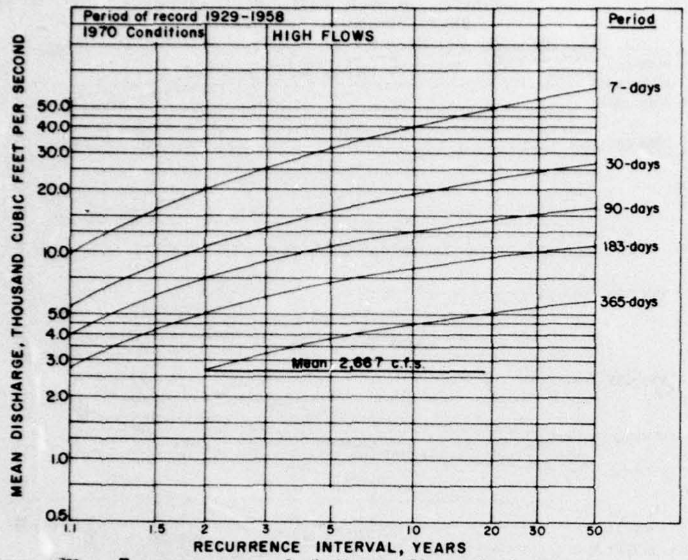


Figure 702 Frequency curves, South Umpqua River nr Brockway

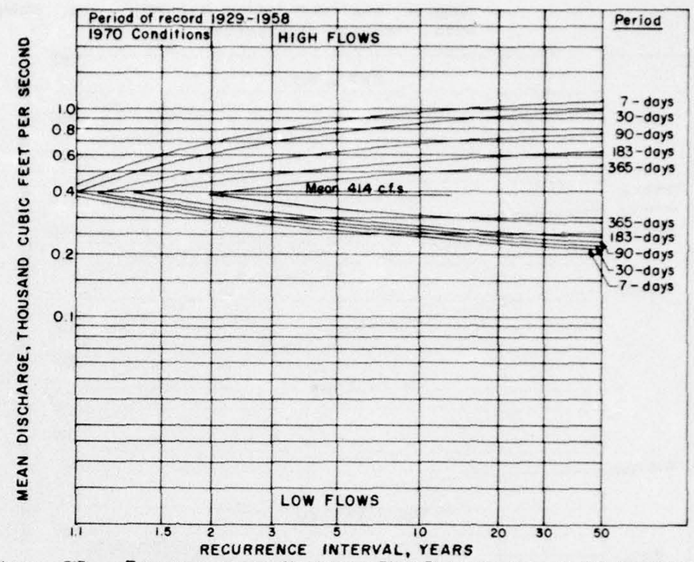


Figure 703 Frequency curves, No. Umpqua River Bl. Lemola Lake Nr. Toketee Falls

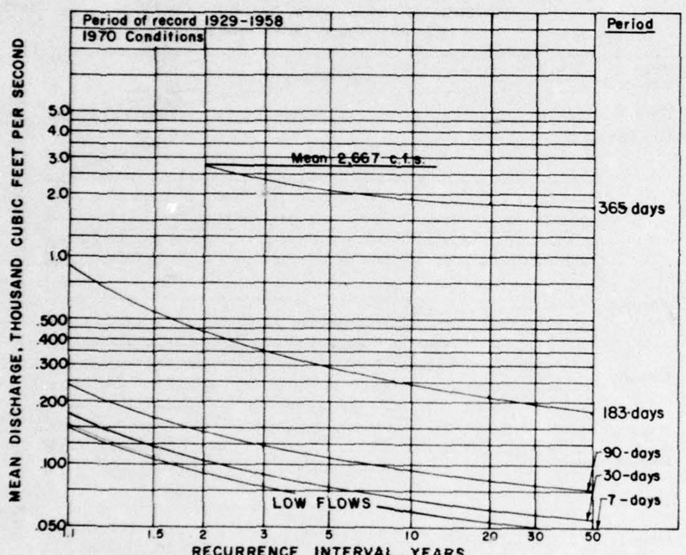


Figure 702 Frequency curves, South Umpqua River nr. Brockway

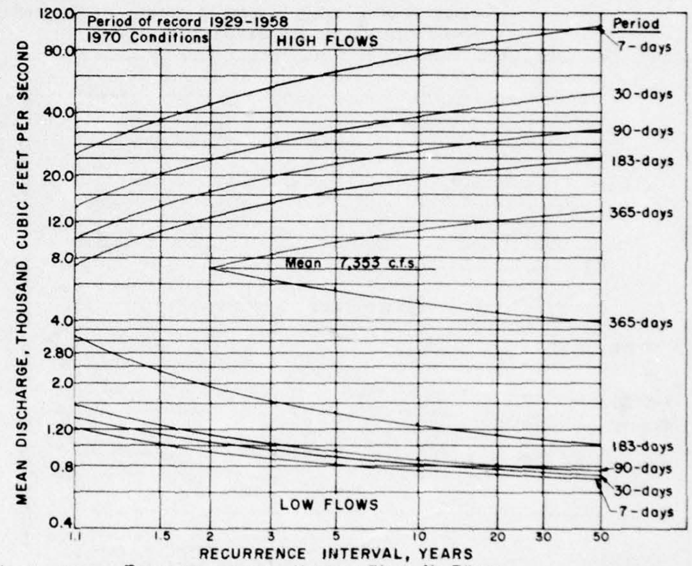


Figure 704 Frequency curves, Umpqua River Nr. Elkton

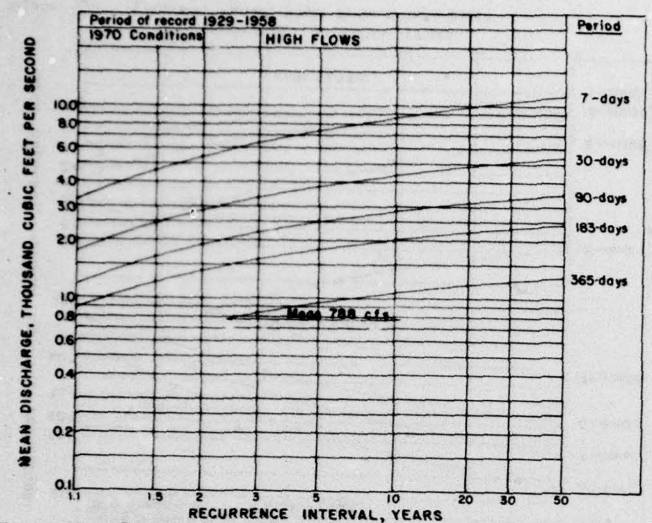


Figure 705 Frequency curves, South Fork Coquille River at Powers

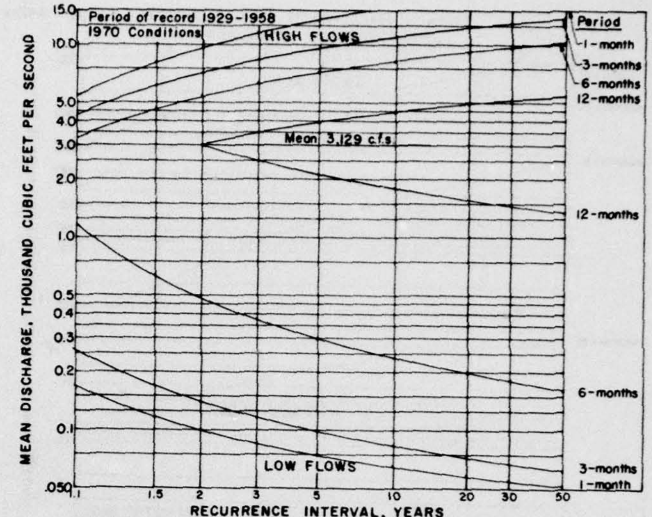


Figure 706 Frequency curves, Coquille River at Coquille

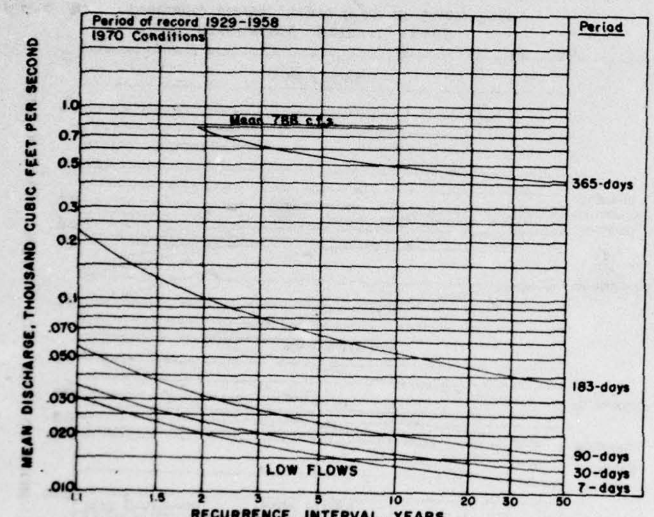


Figure 705 Frequency curves, South Fork Coquille River at Powers

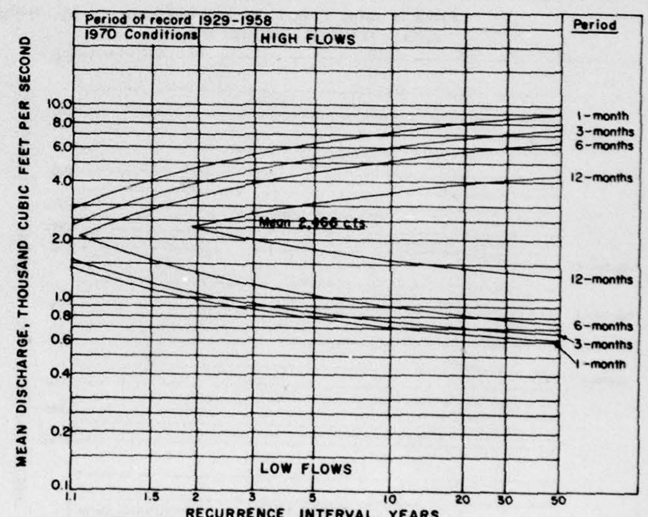


Figure 707 Frequency curves, Rogue River at Dodge Bridge

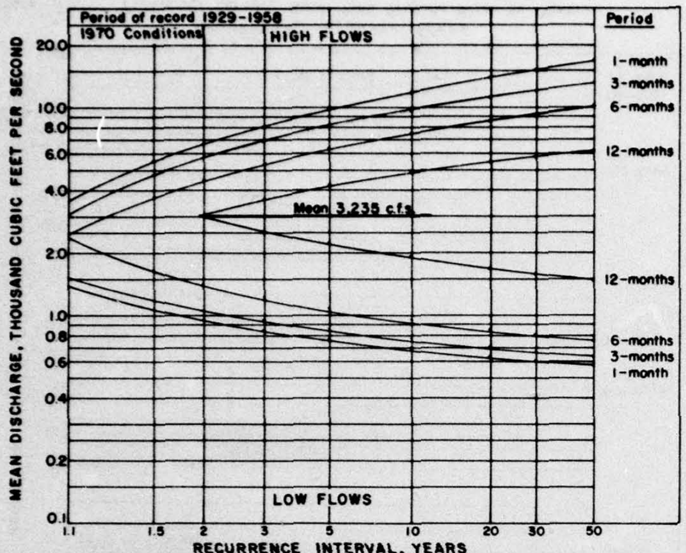


Figure 708 Frequency curves, Rogue River at Grants Pass

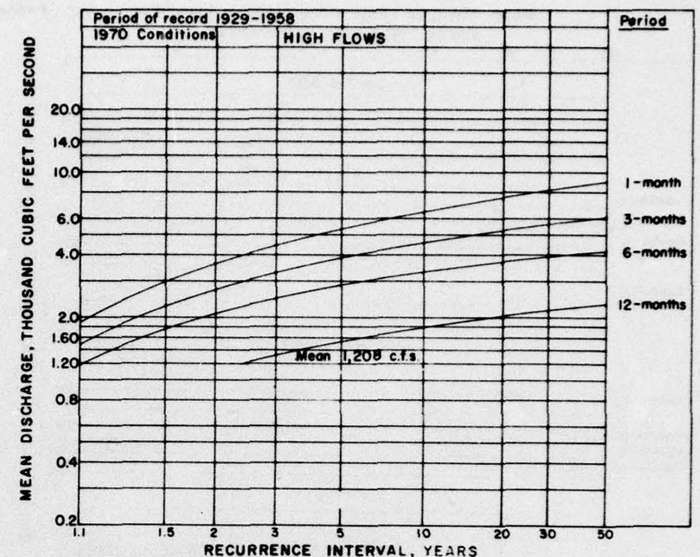


Figure 709 Frequency curves, Illinois River nr Kerby

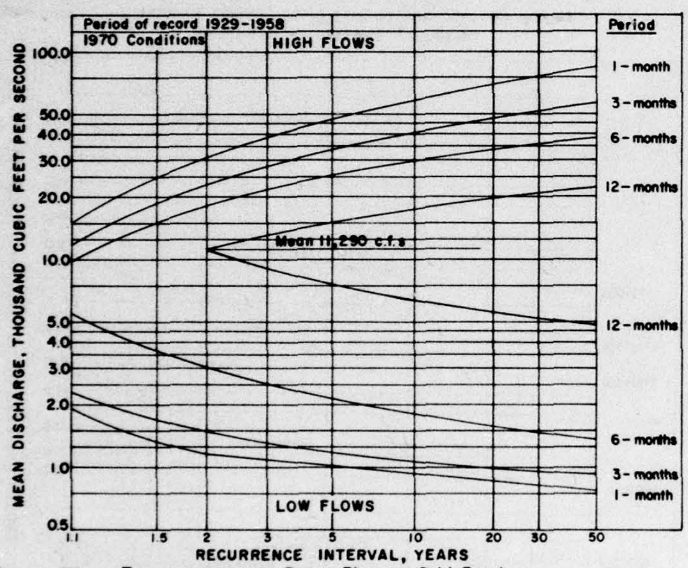


Figure 710 Frequency curves, Rogue River nr Gold Beach

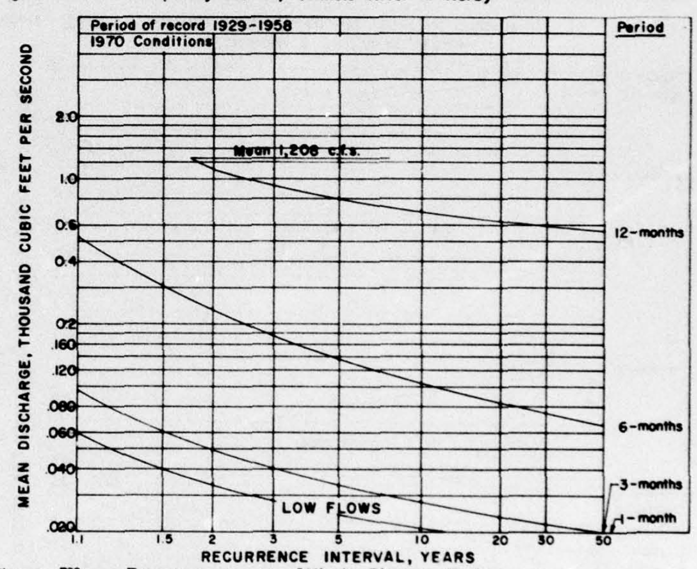


Figure 709 Frequency curves, Illinois River nr. Kerby

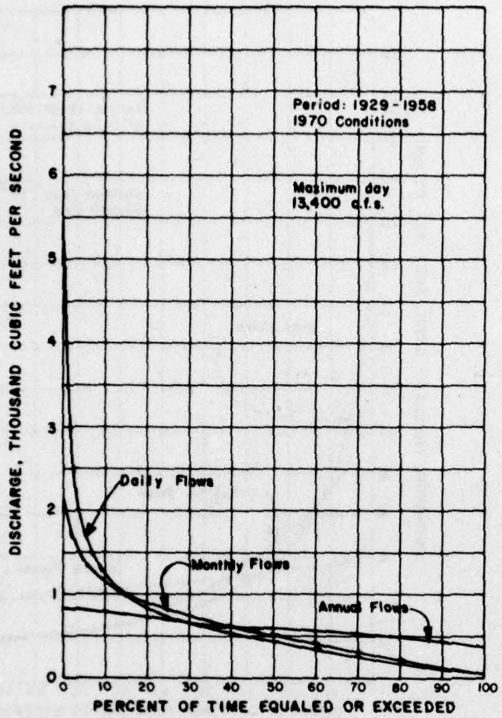


Figure 711 Duration curves, Soleduck River near Fairholm, Washington

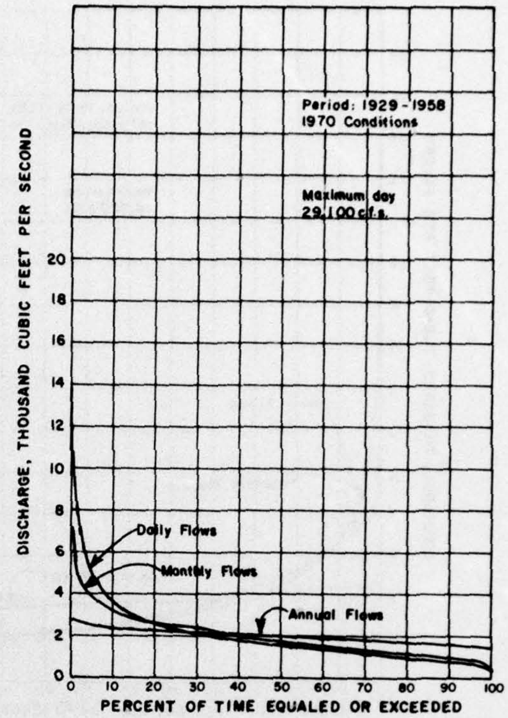


Figure 712 Duration curves, Hoh River near Forks, Wash.

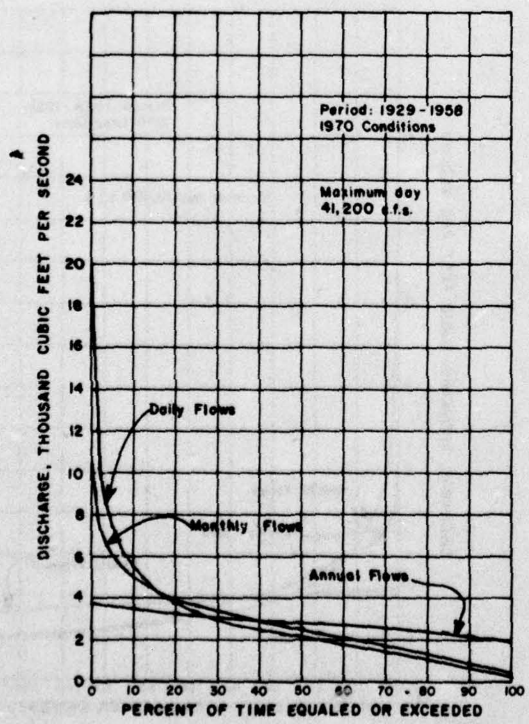


Figure 713 Duration curves, Quinault River at Quinault Lake, Washington

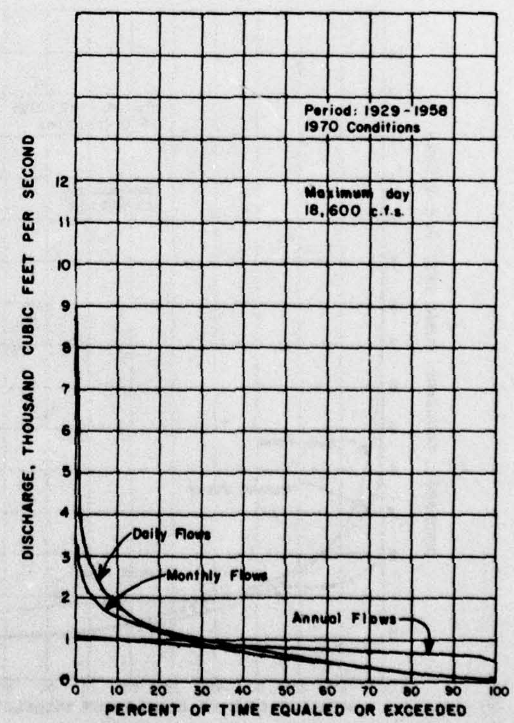


Figure 714 Duration curves, Wynoochee R. above Save Cr. near Aberdeen, Washington

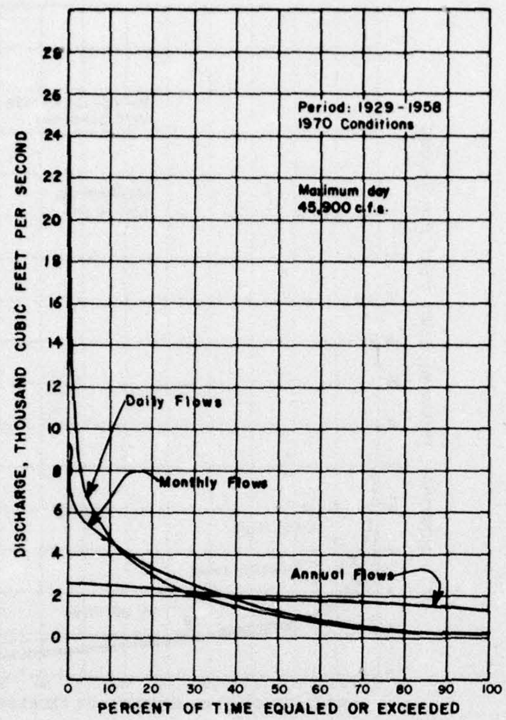


Figure 715 Duration curves, Satsop River near Satsop, Washington

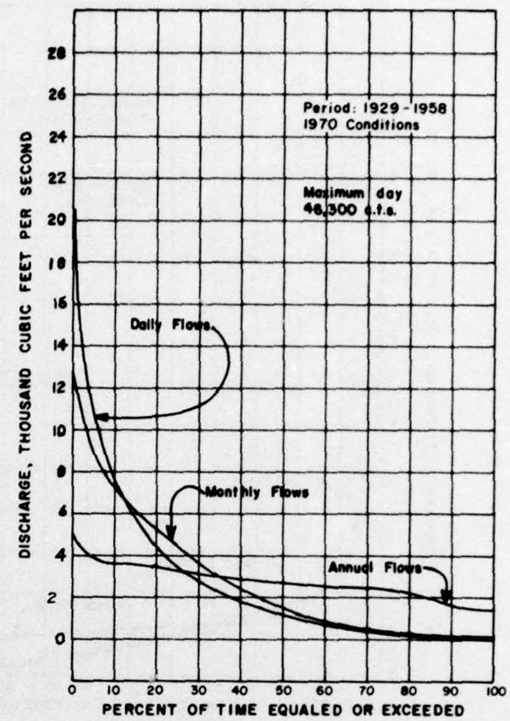


Figure 716 Duration curves, Chehalis River near Grand Mound, Washington

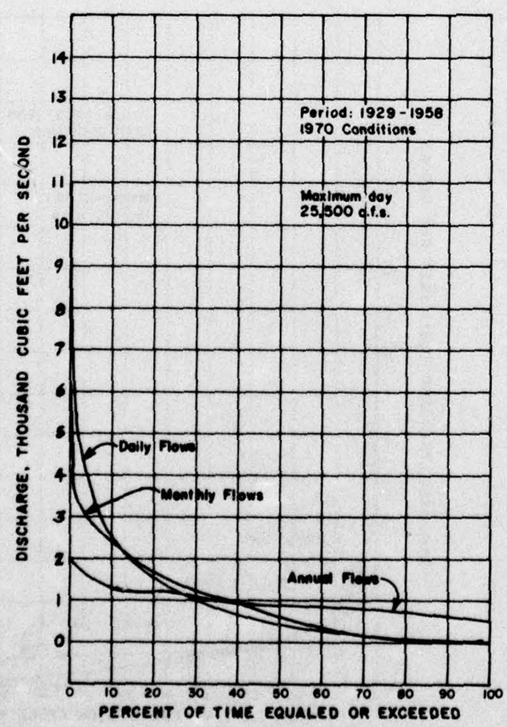


Figure 717 Duration curves, North River near Raymond, Washington

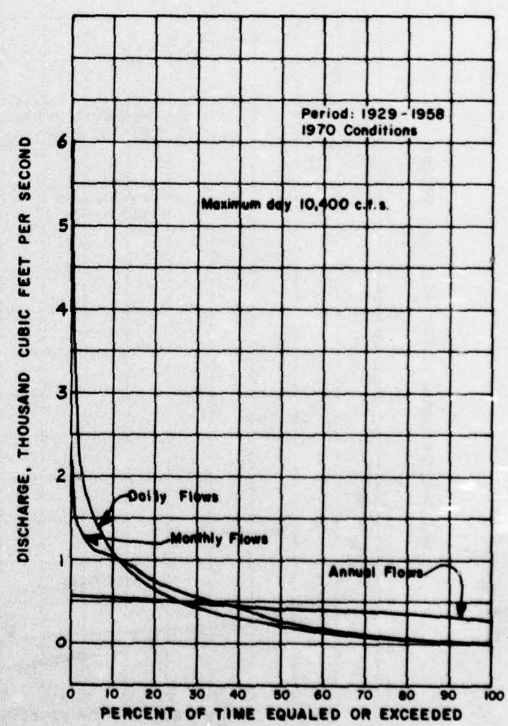


Figure 718 Duration curves, Naselle River, near Naselle, Washington

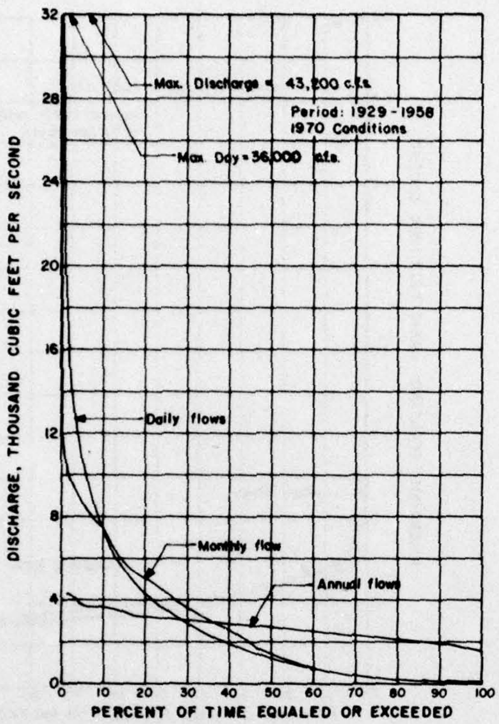


Figure 719 Duration curves, Nehalem River near Foss, Oregon

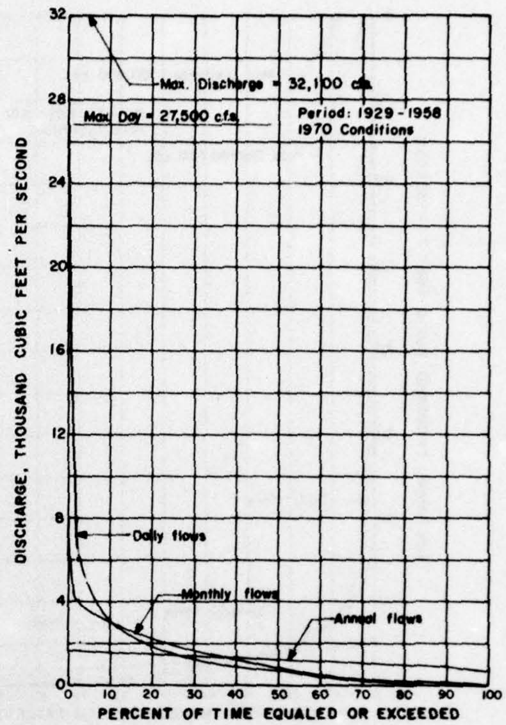


Figure 720 Duration curves, Wilson River near Tillamook, Oregon

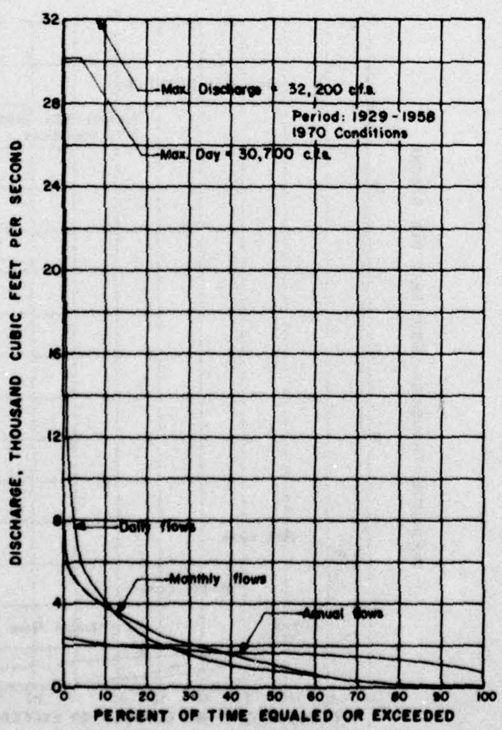


Figure 721 Duration curves, Siletz River at Siletz, Oregon

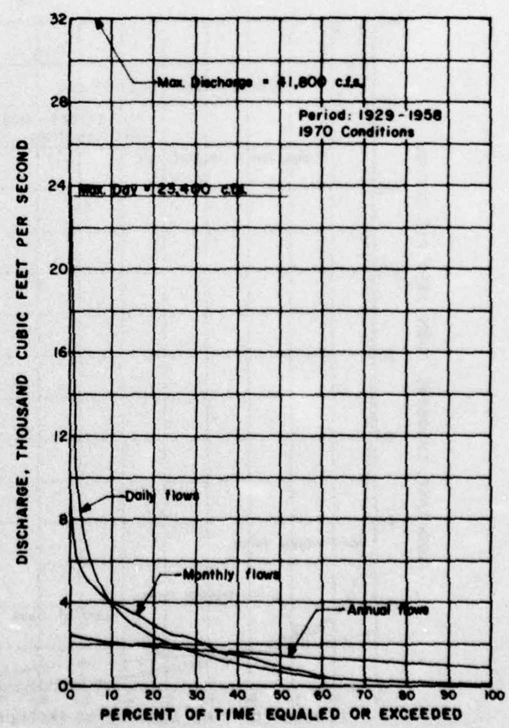


Figure 722 Duration curves, Alsea River near Tidewater, Oregon

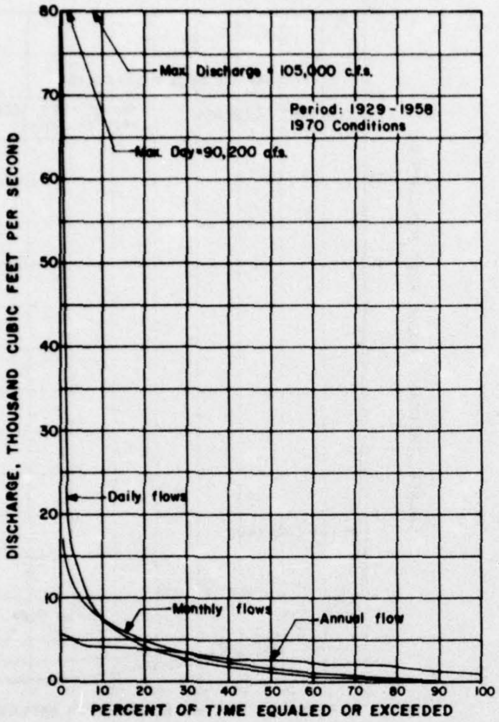


Figure 723 Duration curves, South Umpqua River near Brockway, Oregon

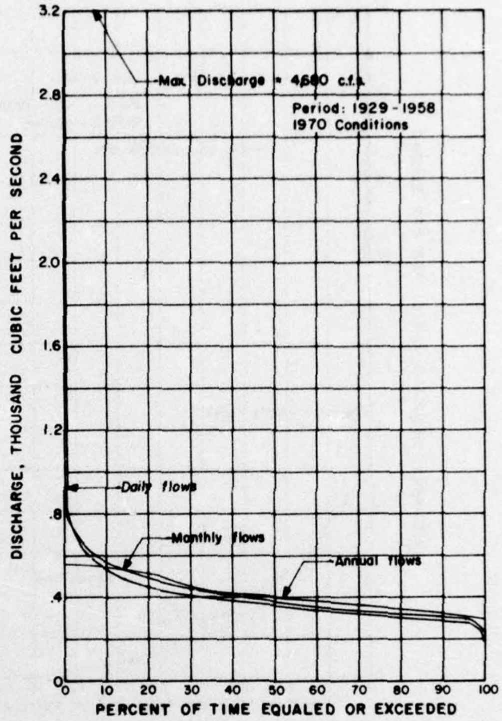


Figure 724 Duration curves, North Umpqua River below Lemolo near Toketee Falls, Oregon

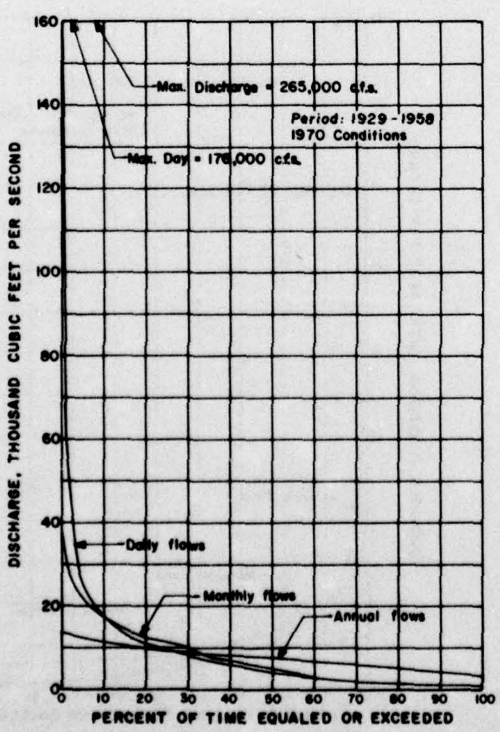


Figure 725 Duration curves, Umpqua River near Elkton, Oregon

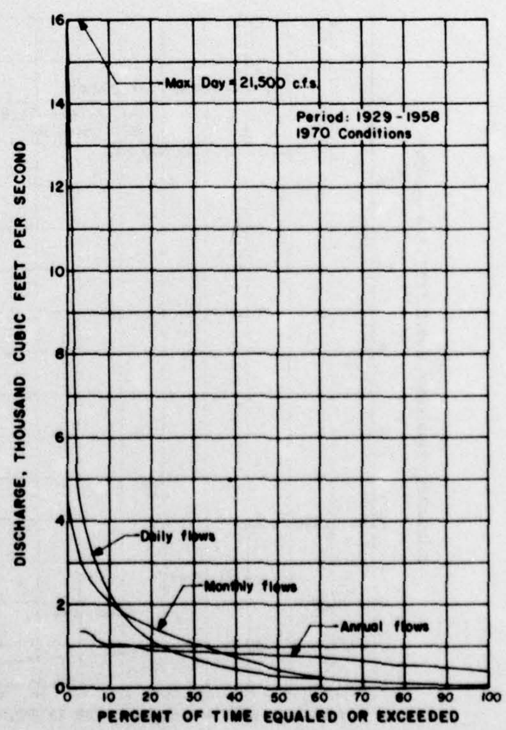


Figure 726 Duration curves, South Fork Coquille River at Powers, Oregon

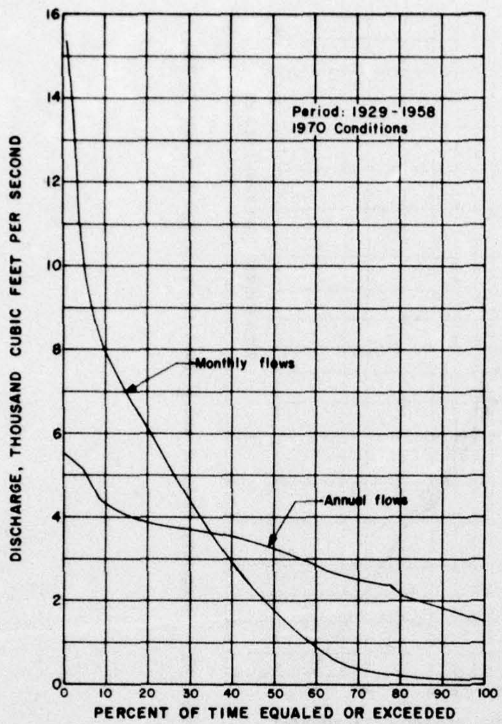


Figure 727 Duration curves, Coquille River at Coquille, Oregon

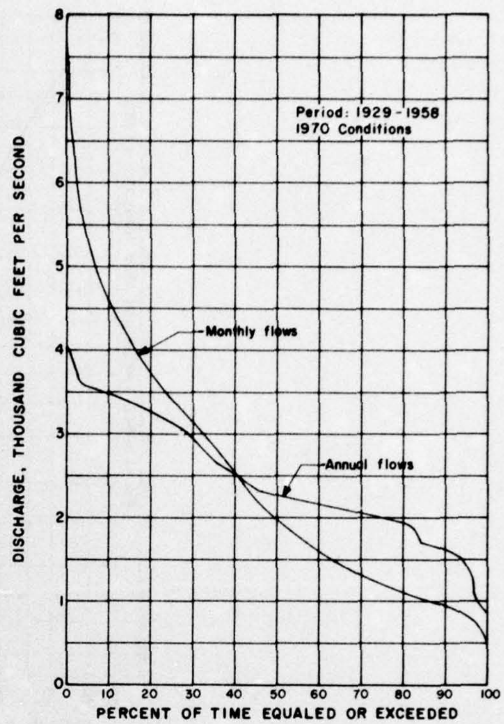


Figure 728 Duration curves, Rogue River at Dodge Bridge, Oregon

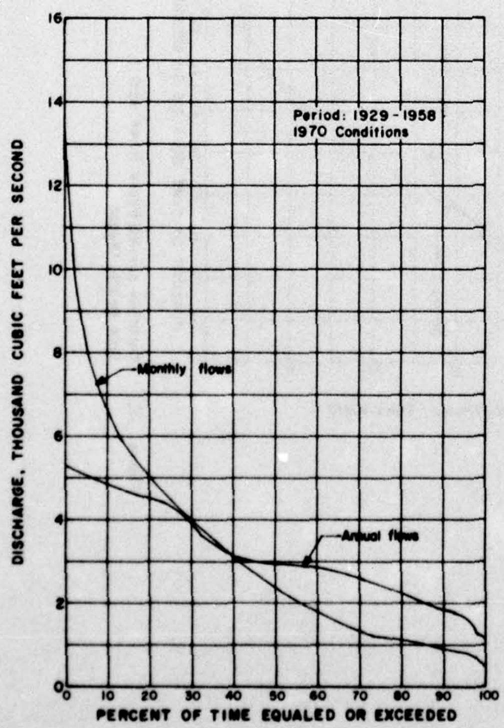


Figure 729 Duration curves, Rogue River at Grants Pass, Oregon

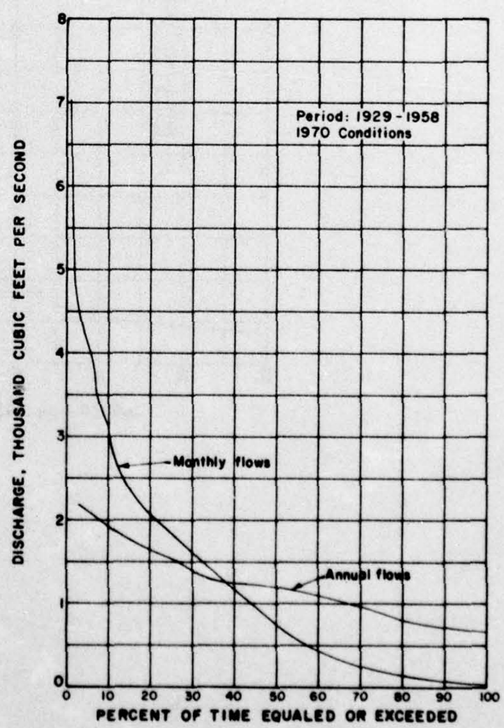


Figure 730 Duration curves, Illinois River near Kerby, Oregon

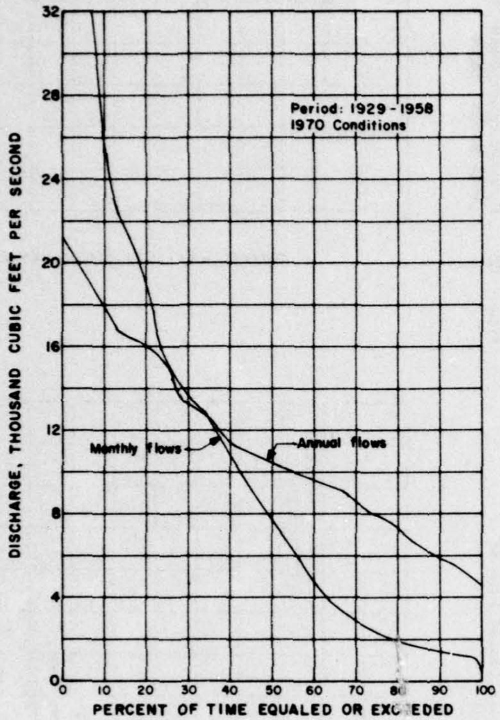


Figure 731 Duration curves, Rogue River near Gold Beach, Oregon

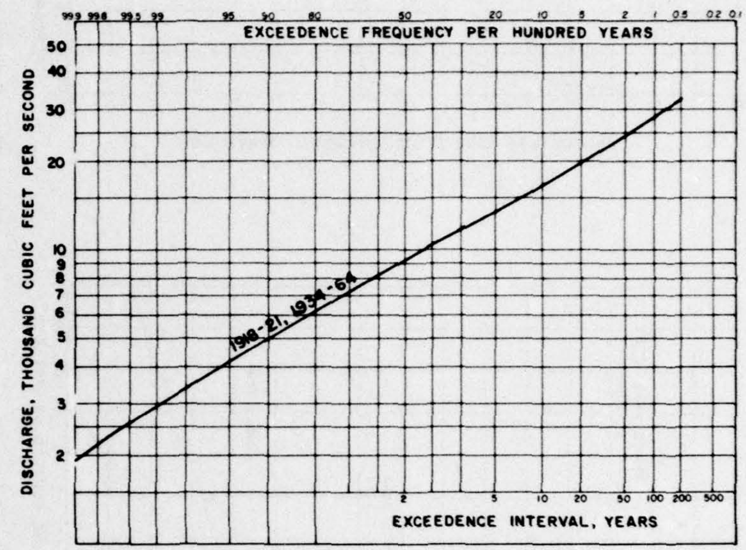


Figure 732 Frequency curve of annual peak flows, Soleduck R. nr. Fairholm, Wash.

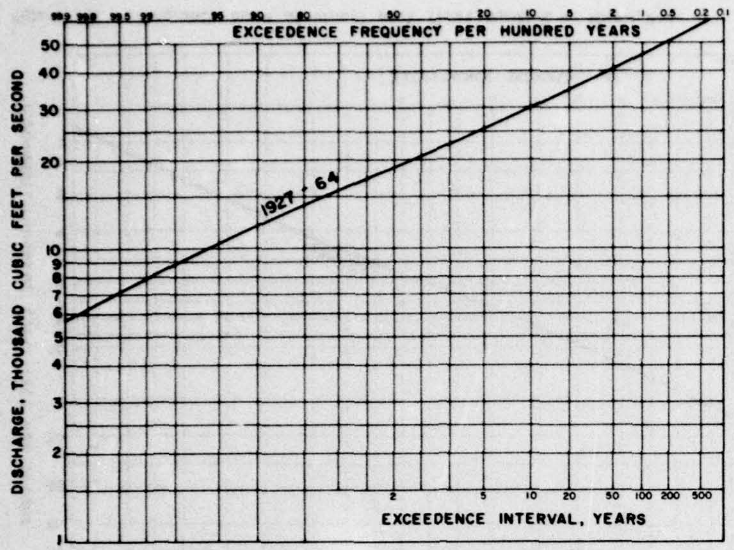


Figure 733 Frequency curve of annual peak flows, Hoh R. nr. Forks, Wash.

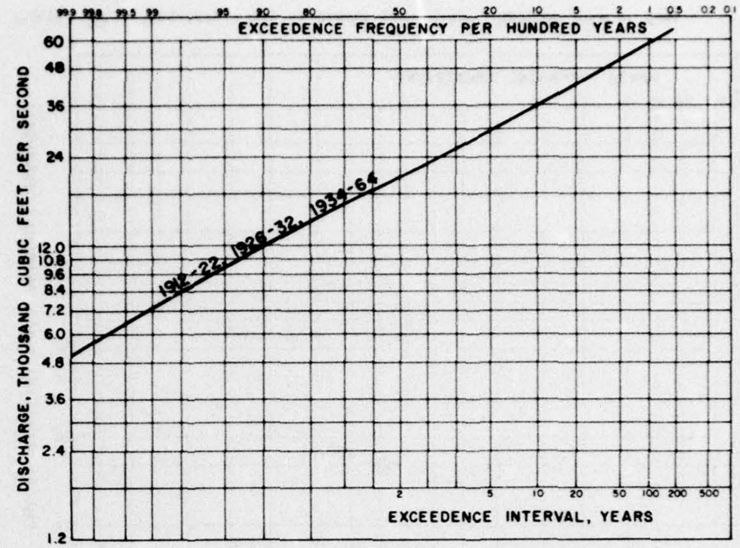


Figure 734 Frequency curve of annual peak flows, Quinault R. at Quinault Lake, Wash.

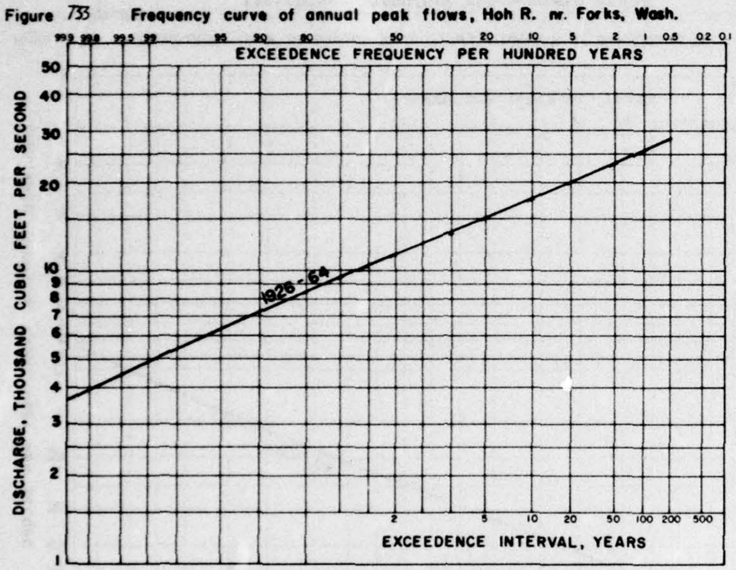


Figure 735 Frequency curve of annual peak flows, Wynoochee R. above Save Cr. nr. Aberdeen, Wash.

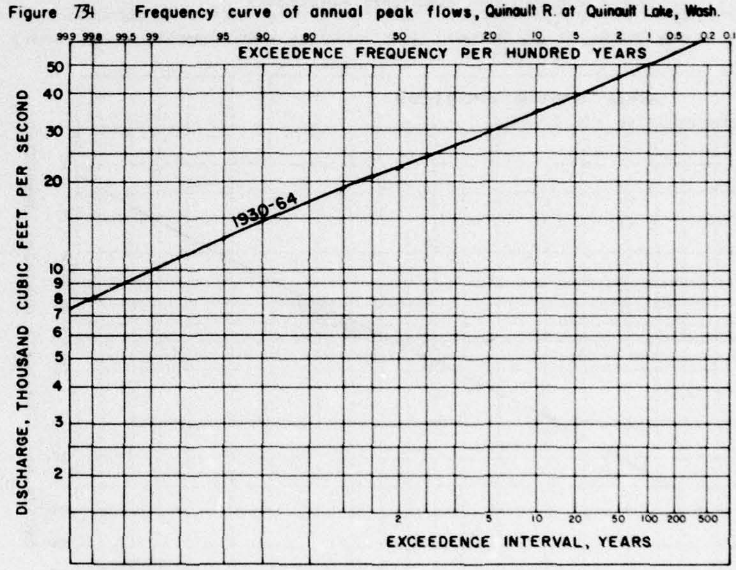


Figure 736 Frequency curve of annual peak flows, Satsop R. nr. Satsop, Wash.

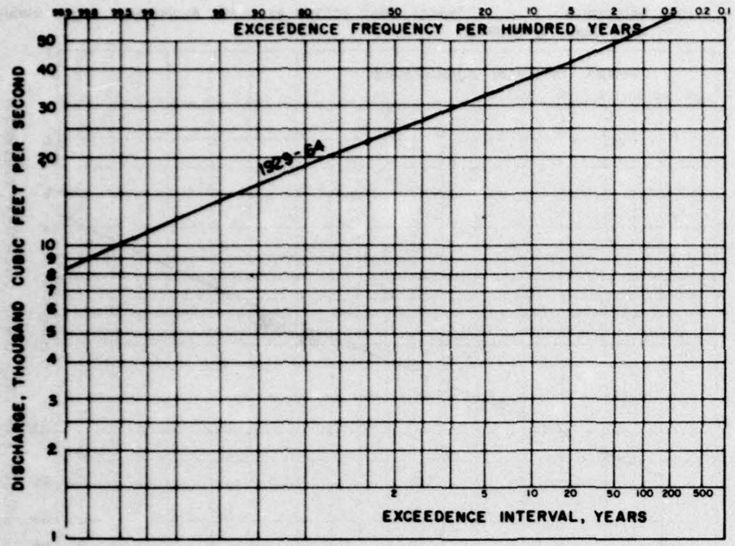


Figure 737 Frequency curve of annual peak flows, Chehalis R. nr. Grand Mound, Wash.

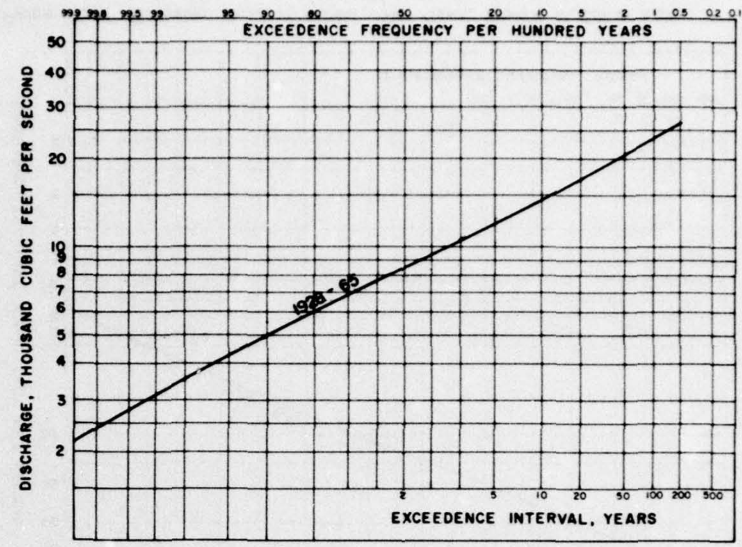


Figure 738 Frequency curve of annual peak flows, North R. nr. Raymond, Wash.

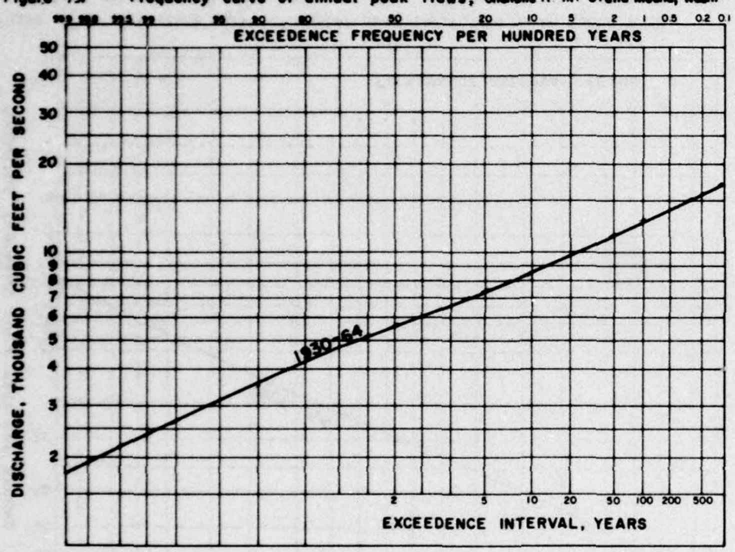


Figure 739 Frequency curve of annual peak flows, Naselle R. nr. Naselle, Wash.

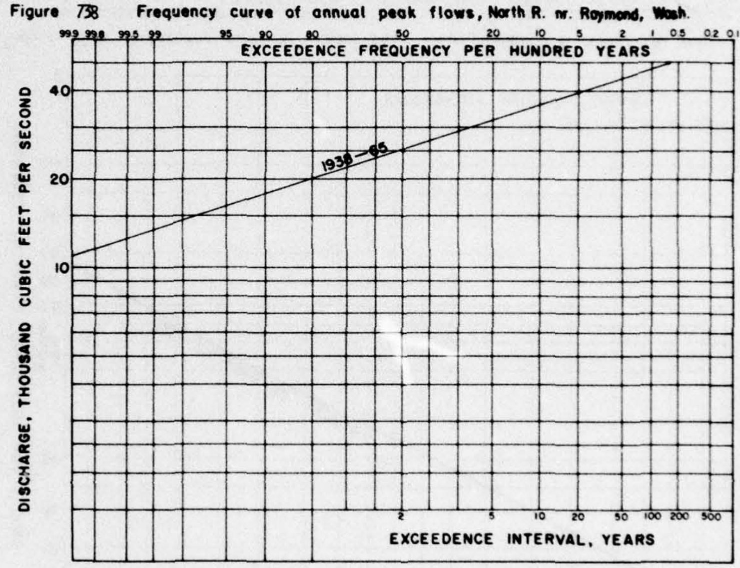


Figure 740 Frequency curve of annual peak flows, Nehalem River nr Foss

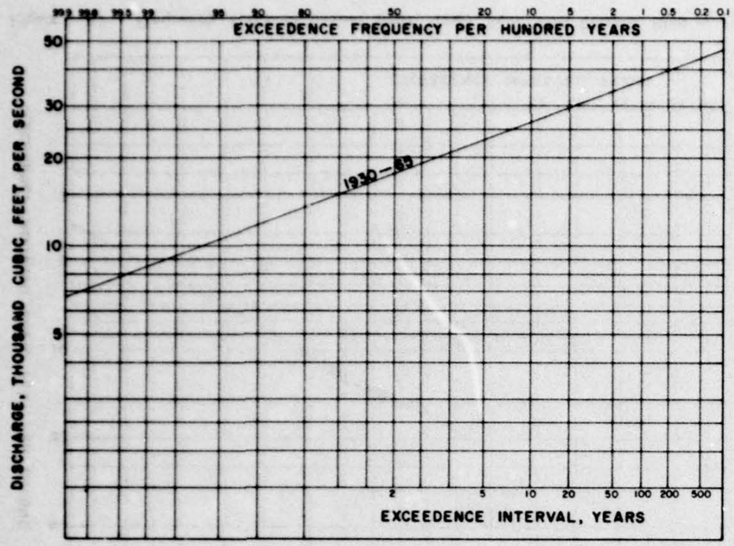


Figure 741 Frequency curve of annual peak flows, Wilson River Nr. Tillamook

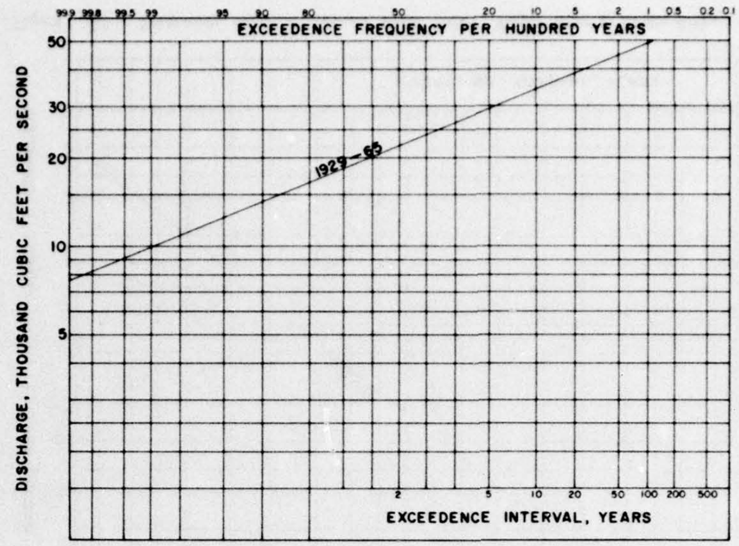


Figure 742 Frequency curve of annual peak flows, Siletz River at Siletz

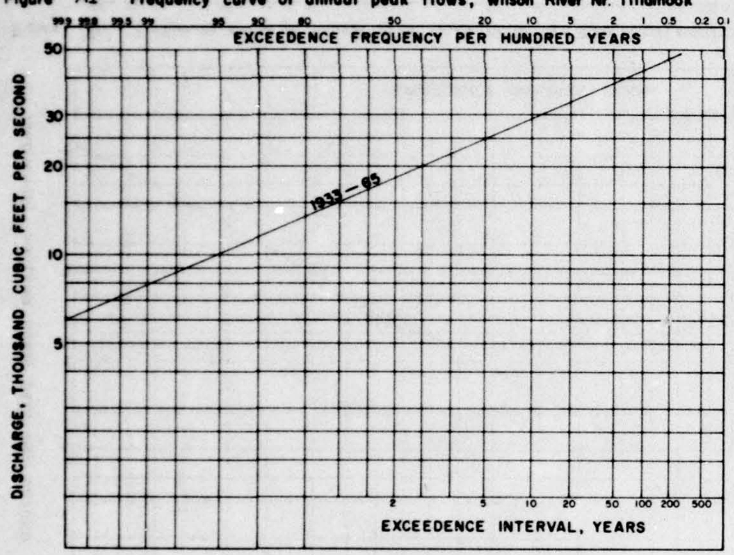


Figure 743 Frequency curve of annual peak flows, Alsea River nr Tidewater

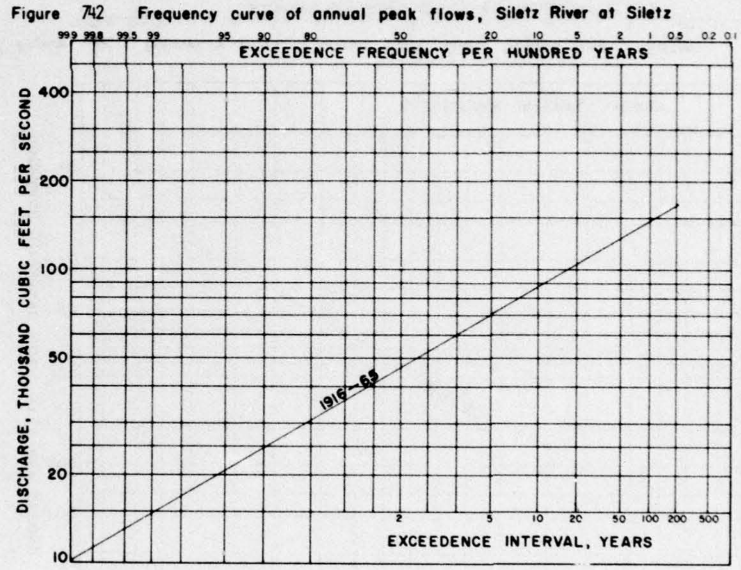


Figure 744 Frequency curve of annual peak flows, South Umpqua River nr Brockway

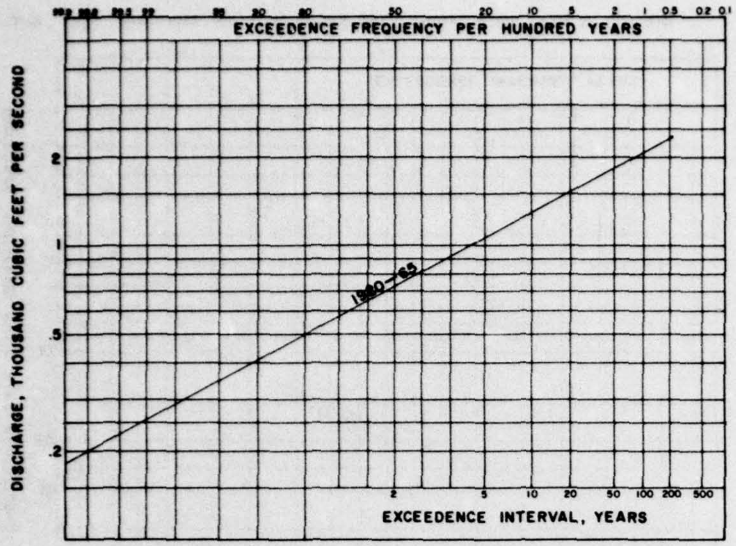


Figure 745 Frequency curve of annual peak flows, No. Umpqua River below Lemolo Lk. Toketee F.

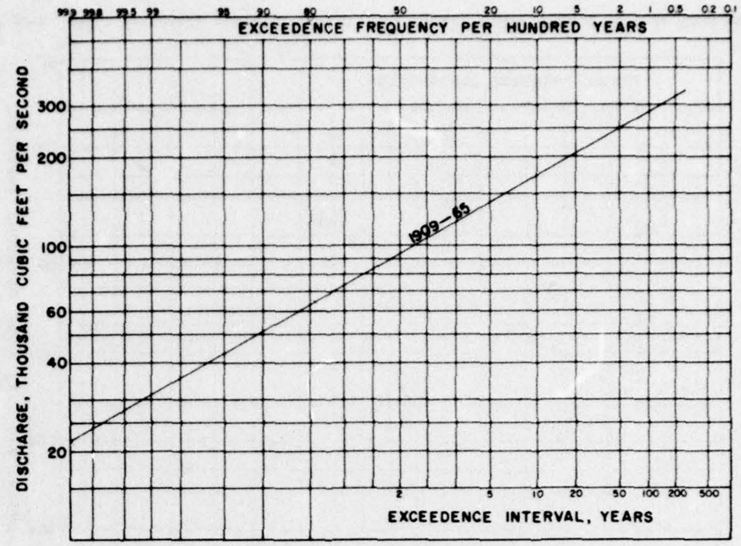


Figure 746 Frequency curve of annual peak flows, Umpqua River nr Elkton

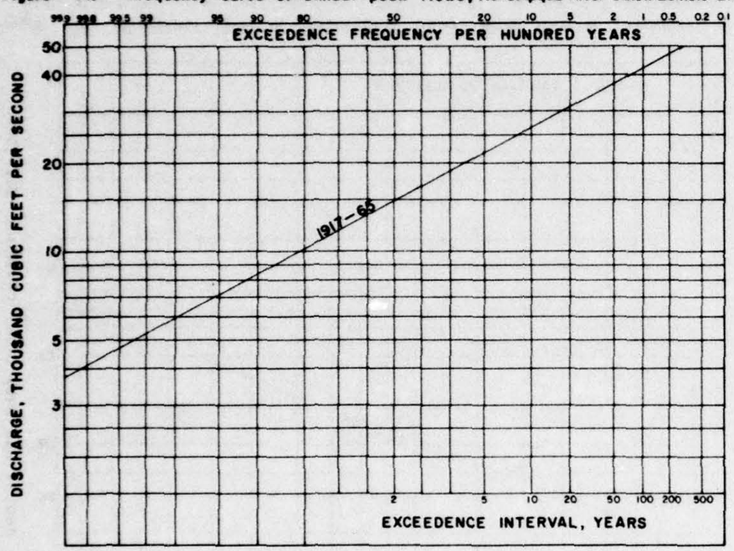


Figure 747 Frequency curve of annual peak flows, South Fork Coquille River at Powers

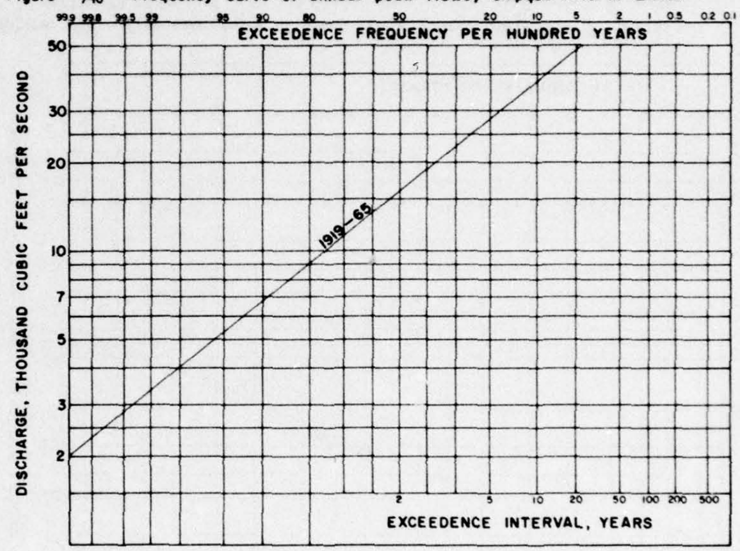


Figure 748 Frequency curve of annual peak flows, Rogue River at Dodge Bridge

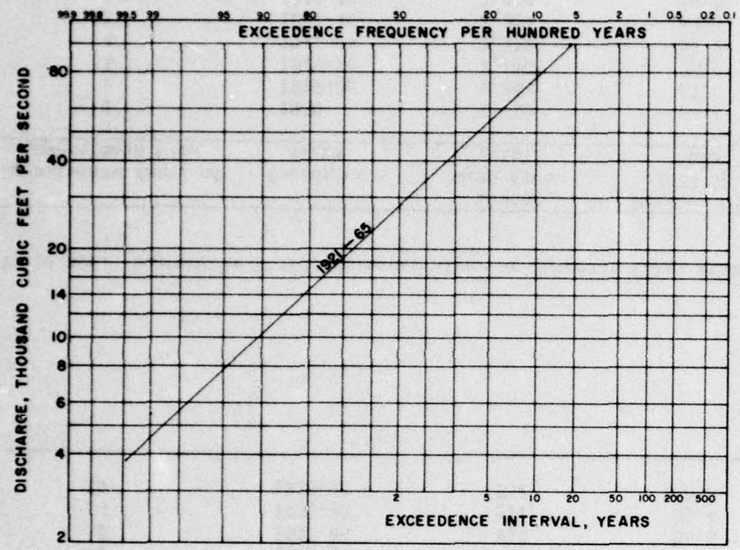


Figure 749 Frequency curve of annual peak flows, Rogue River at Grants Pass

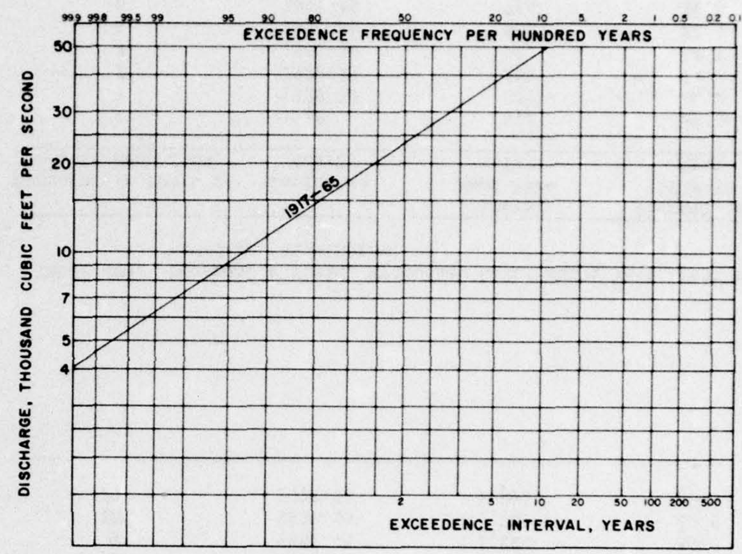


Figure 750 Frequency curve of annual peak flows, Illinois River nr. Kerby

Table 401. Dependable Yield, Soleduck River near Fairholm, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	359	60.0
2	1929-30	414	69.2
3	1942-44	450	75.2
4	1941-44	459	76.8
5	1941-45	478	79.9
6	1940-45	501	83.8
7	1939-45	508	84.9
8	1938-45	519	86.8
9	1937-45	512	85.6
10	1936-45	511	85.4
30	1929-58	598	100.0

Table 402. Dependable Yield, Hoh River near Forks, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	1,396	70.1
2	1929-30	1,522	76.4
3	1942-44	1,618	81.3
4	1941-44	1,657	83.2
5	1941-45	1,716	86.2
6	1940-45	1,777	89.2
7	1939-45	1,793	90.0
8	1938-45	1,805	90.6
9	1937-45	1,782	89.5
10	1936-45	1,789	89.8
30	1929-58	1,991	100.0

Table 403. Dependable Yield, Quinault River at Quinault Lake, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	1,780	64.4
2	1929-30	1,868	67.6
3	1929-31	2,100	76.0
4	1941-44	2,215	80.2
5	1941-45	2,304	83.4
6	1940-45	2,400	86.8
7	1939-45	2,416	87.4
8	1938-45	2,463	89.2
9	1937-45	2,441	88.4
10	1936-45	2,437	88.1
30	1929-58	2,766	100.0

Table 404. Dependable Yield, Wynoochee River above Save Creek near Aberdeen, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	512	64.2
2	1929-30	527	66.0
3	1929-31	595	74.6
4	1941-44	671	84.1
5	1941-45	695	87.1
6	1940-45	714	89.5
7	1939-45	709	88.8
8	1938-45	723	90.6
9	1937-45	715	89.6
10	1936-45	712	89.2
30	1929-58	798	100.0

Table 405. Dependable Yield, Satsop River near Satsop, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	1,238	63.8
2	1929-30	1,369	70.5
3	1942-44	1,469	75.6
4	1941-44	1,479	76.2
5	1941-45	1,549	79.9
6	1939-44	1,564	80.5
7	1939-45	1,601	82.4
8	1939-46	1,672	86.0
9	1937-45	1,687	86.9
10	1936-45	1,687	86.9
30	1929-58	1,944	100.0

Table 406. Dependable Yield, Chehalis River near Grand Mound, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	1,569	56.8
2	1929-30	1,665	60.3
3	1929-31	1,787	64.7
4	1941-44	2,013	72.9
5	1941-45	2,057	74.5
6	1940-45	2,157	78.1
7	1939-45	2,169	78.6
8	1939-46	2,257	81.7
9	1939-47	2,310	83.7
10	1939-48	2,294	83.1
30	1929-58	2,761	100.0

Table 407. Dependable Yield, North River near Raymond, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	589	62.6
2	1929-30	621	66.0
3	1929-31	677	62.0
4	1941-44	682	62.5
5	1941-45	690	73.4
6	1940-45	720	76.5
7	1939-45	733	77.9
8	1939-46	766	81.4
9	1939-47	772	82.0
10	1939-48	798	84.9
30	1929-58	941	100.0

Table 408. Dependable Yield, Naselle River near Naselle, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	264	62.1
2	1929-30	287	67.5
3	1929-31	309	72.7
4	1941-44	337	79.3
5	1941-45	350	81.6
6	1940-45	360	84.7
7	1939-45	362	85.2
8	1938-45	374	88.0
9	1937-45	372	87.5
10	1936-45	372	87.5
30	1929-58	425	100.0

Table 409. Dependable Yield, Nehalem River near Foss, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	1,582	59.1
2	1940-41	1,930	72.1
3	1929-31	2,032	75.9
4	1939-42	2,108	78.8
5	1940-42	2,176	81.3
6	1939-44	2,159	80.6
7	1939-45	2,170	81.1
8	1935-42	2,387	89.3
9	1939-47	2,327	87.0
10	1936-45	2,319	86.5
30	1929-58	2,675	100.0

Table 410. Dependable Yield, Wilson River near Tillamook, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	734	62.7
2	1941-42	838	71.6
3	1939-41	892	76.1
4	1939-42	905	77.4
5	1939-43	982	83.9
6	1939-44	945	80.8
7	1939-45	960	82.1
8	1939-46	1,010	86.4
9	1937-45	1,014	86.7
10	1936-45	1,023	87.8
30	1929-58	1,171	100.0

Table 411. Dependable Yield, Siletz River at Siletz

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	879	57.7
2	1941-42	1,049	68.9
3	1939-41	1,125	74.0
4	1939-42	1,146	75.3
5	1940-44	1,203	79.1
6	1939-44	1,230	80.8
7	1939-45	1,247	81.9
8	1940-46	1,299	85.3
9	1936-44	1,317	86.5
10	1936-45	1,311	86.3
30	1929-58	1,521	100.0

Table 412. Dependable Yield, Alsea River Near Tidewater

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (CFS)	Percent of 1929-58 Mean
1	1941	881	57.0
2	1941-42	1,033	66.9
3	1939-46	1,075	69.5
4	1939-42	1,103	71.4
5	1940-44	1,203	77.9
6	1939-44	1,194	77.3
7	1939-45	1,208	78.2
8	1939-46	1,250	80.9
9	1939-47	1,265	81.9
10	1936-45	1,311	84.9
30	1929-58	1,545	100.0

Table 413. Dependable Yield, South Umpqua near Brockway

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	907	34.0
2	1930-31	1,183	44.4
3	1929-31	1,218	45.7
4	1929-32	1,566	58.8
5	1930-34	1,703	64.0
6	1929-34	1,634	61.3
7	1929-35	1,763	66.2
8	1929-36	1,849	69.4
9	1929-37	1,869	70.2
10	1929-38	2,089	78.4
30	1929-58	2,667	100.0

Table 414. Dependable Yield, North Umpqua River below Lemolo Lake near Toketee Falls

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	295	71.1
2	1930-31	317	76.4
3	1930-32	325	78.3
4	1929-32	330	79.5
5	1929-33	345	83.1
6	1929-34	345	83.1
7	1929-35	347	83.5
8	1929-36	350	84.3
9	1929-37	350	84.3
10	1929-38	358	86.3
30	1929-58	414	100.0

Table 415. Dependable Yield, Umpqua River near Elkton

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	3,150	42.8
2	1930-31	3,785	51.5
3	1929-31	3,947	53.7
4	1929-32	4,843	65.9
5	1930-34	5,392	73.3
6	1929-34	5,041	68.6
7	1929-35	5,383	73.2
8	1929-36	5,556	75.6
9	1929-37	5,596	76.1
10	1929-38	6,101	83.0
30	1929-58	7,353	100.0

Table 416. Dependable Yield, South Fork Coquille River at Powers

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	396	50.4
2	1930-31	408	52.0
3	1929-31	450	57.3
4	1929-32	534	68.0
5	1930-34	593	75.5
6	1929-34	584	74.4
7	1929-35	614	78.2
8	1929-36	632	80.5
9	1929-37	622	79.2
10	1930-39	687	87.5
30	1929-58	785	100.0

Table 417. Dependable Yield, Coquille River at Coquille

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1,569	50.1
2	1930-31	1,624	51.9
3	1929-31	1,792	57.2
4	1929-32	2,124	67.8
5	1930-34	2,354	75.2
6	1929-34	2,317	74.0
7	1929-35	2,440	77.9
8	1930-36	2,514	80.3
9	1929-36	2,472	78.9
10	1930-38	2,751	87.9
30	1929-58	3,129	100.0

Table 418. Dependable Yield, Rogue River at Dodge Bridge

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	970	39.4
2	1930-31	1,251	50.8
3	1929-31	1,362	55.3
4	1929-32	1,582	64.2
5	1930-34	1,693	68.8
6	1929-34	1,675	68.0
7	1929-35	1,771	71.9
8	1929-36	1,828	74.2
9	1929-37	1,787	72.5
10	1929-38	1,971	80.0
30	1929-58	2,465	100.0

Table 419. Dependable Yield, Rogue River at Grants Pass

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1,156	35.8
2	1930-31	1,544	47.7
3	1929-31	1,644	50.8
4	1929-32	1,971	60.9
5	1930-34	2,129	65.8
6	1929-34	2,082	64.4
7	1929-35	2,214	68.4
8	1929-36	2,303	71.3
9	1929-37	2,342	72.4
10	1929-38	2,572	79.5
30	1929-58	3,235	100.0

Table 420. Dependable Yield, Illinois River near Kerby

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	576	47.6
2	1930-31	698	57.6
3	1929-31	714	59.0
4	1929-32	796	65.8
5	1929-33	886	73.3
6	1929-34	836	69.1
7	1929-35	881	72.9
8	1929-36	904	74.7
9	1929-37	901	74.5
10	1930-39	985	81.4
30	1929-58	1,208	100.0

Table 421. Dependable Yield, Rogue River near Gold Beach

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	4,621	40.9
2	1930-31	5,940	52.7
3	1929-31	6,079	53.8
4	1929-32	6,963	61.6
5	1930-34	7,516	66.5
6	1929-34	7,325	64.8
7	1929-35	7,788	68.9
8	1929-36	8,085	71.6
9	1929-37	8,147	72.1
10	1929-38	9,131	80.8
30	1929-58	11,290	100.0

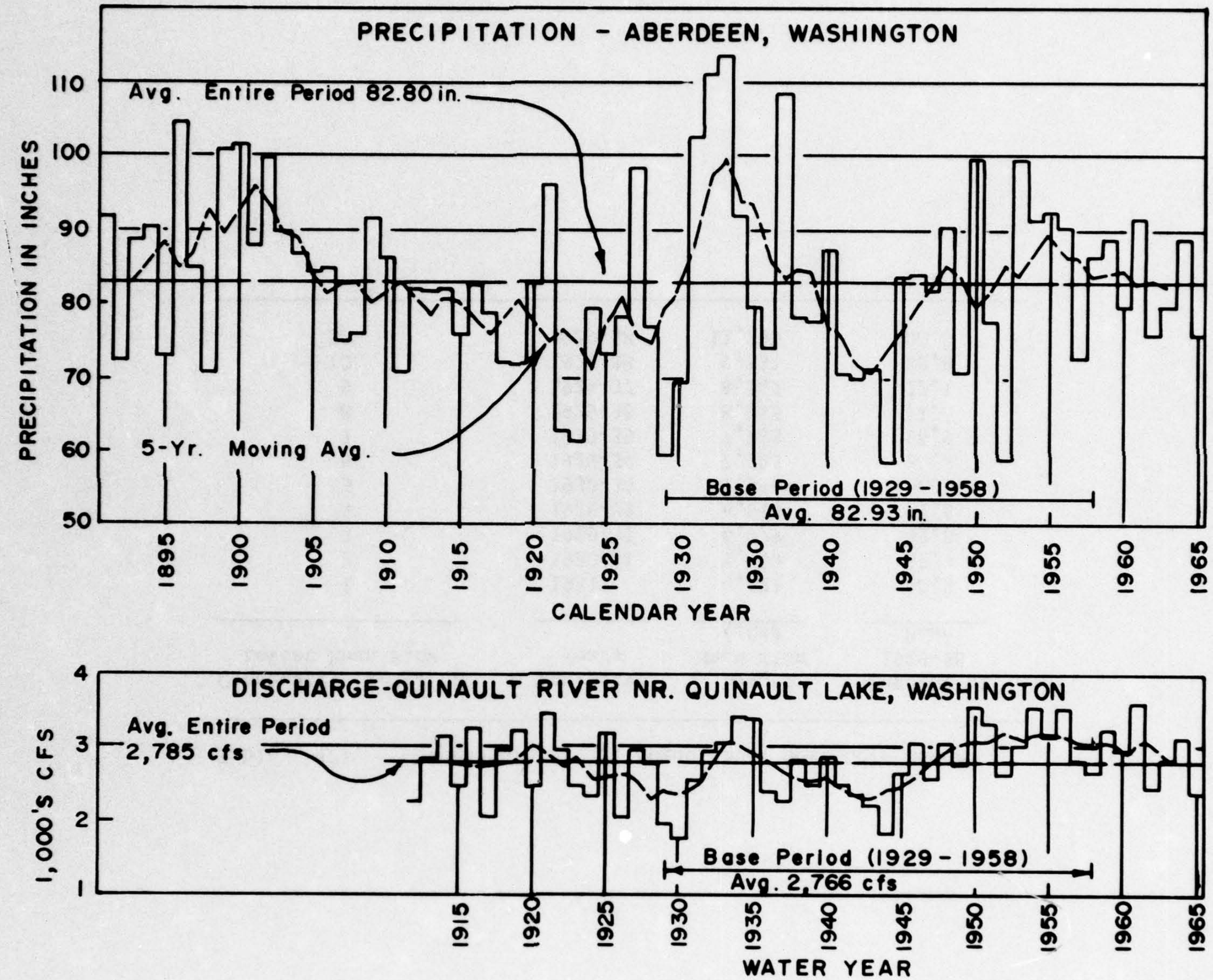


Figure 751. Long-term variation in precipitation and streamflow.

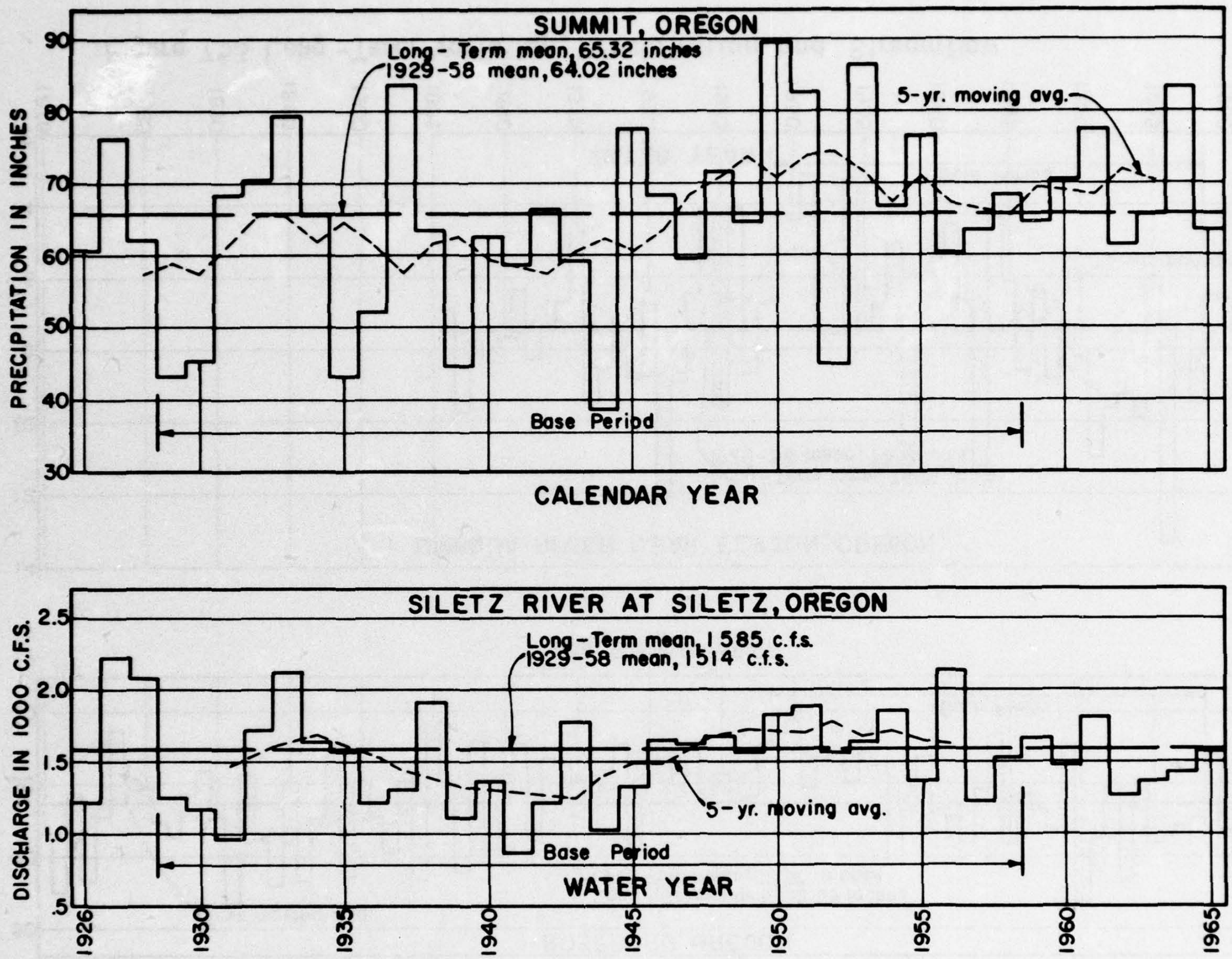


Figure 752. Long-Term Variation, Precipitation and Streamflow.

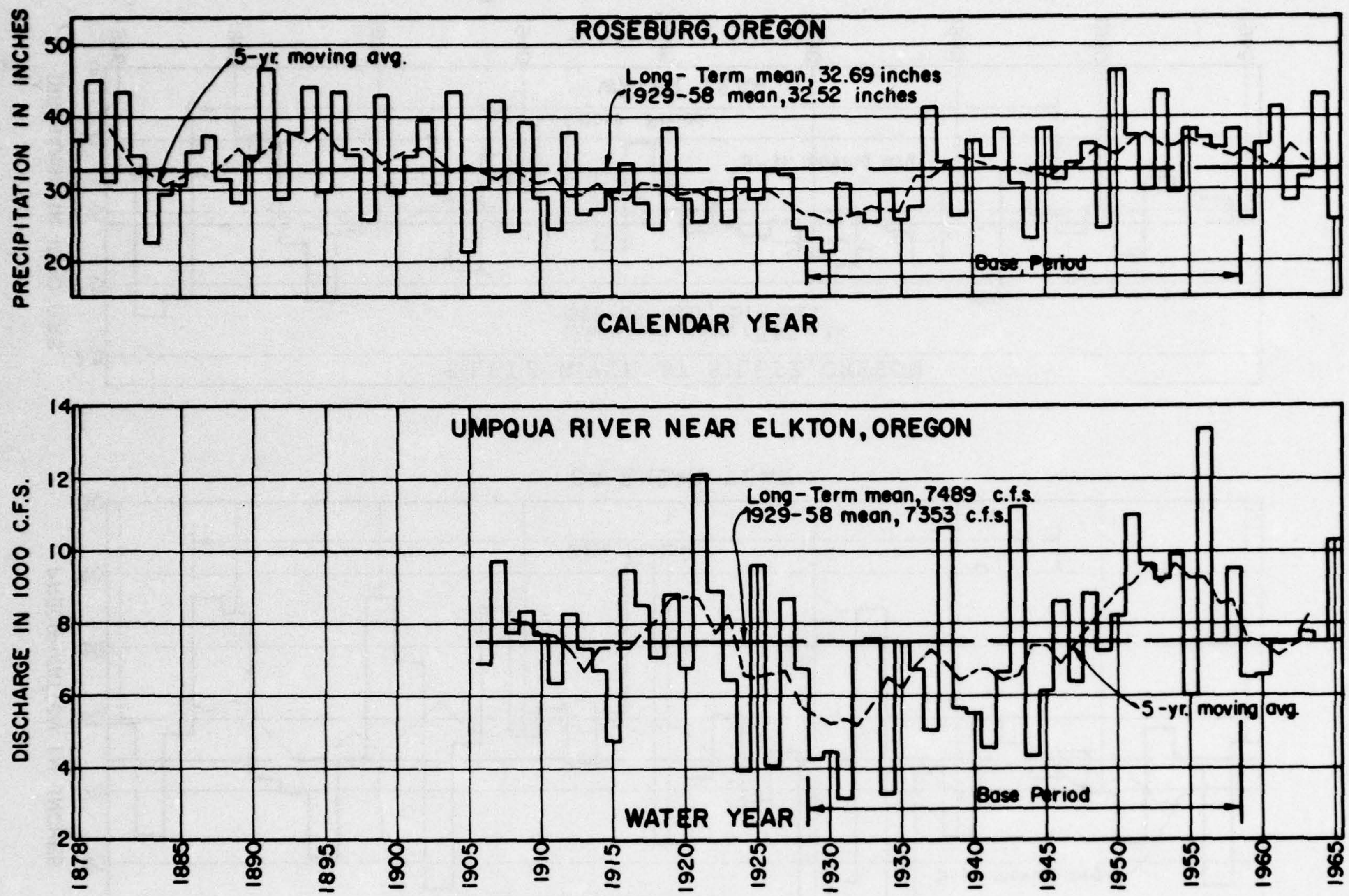


Figure 753. Long-Term Variation, Precipitation and Streamflow.

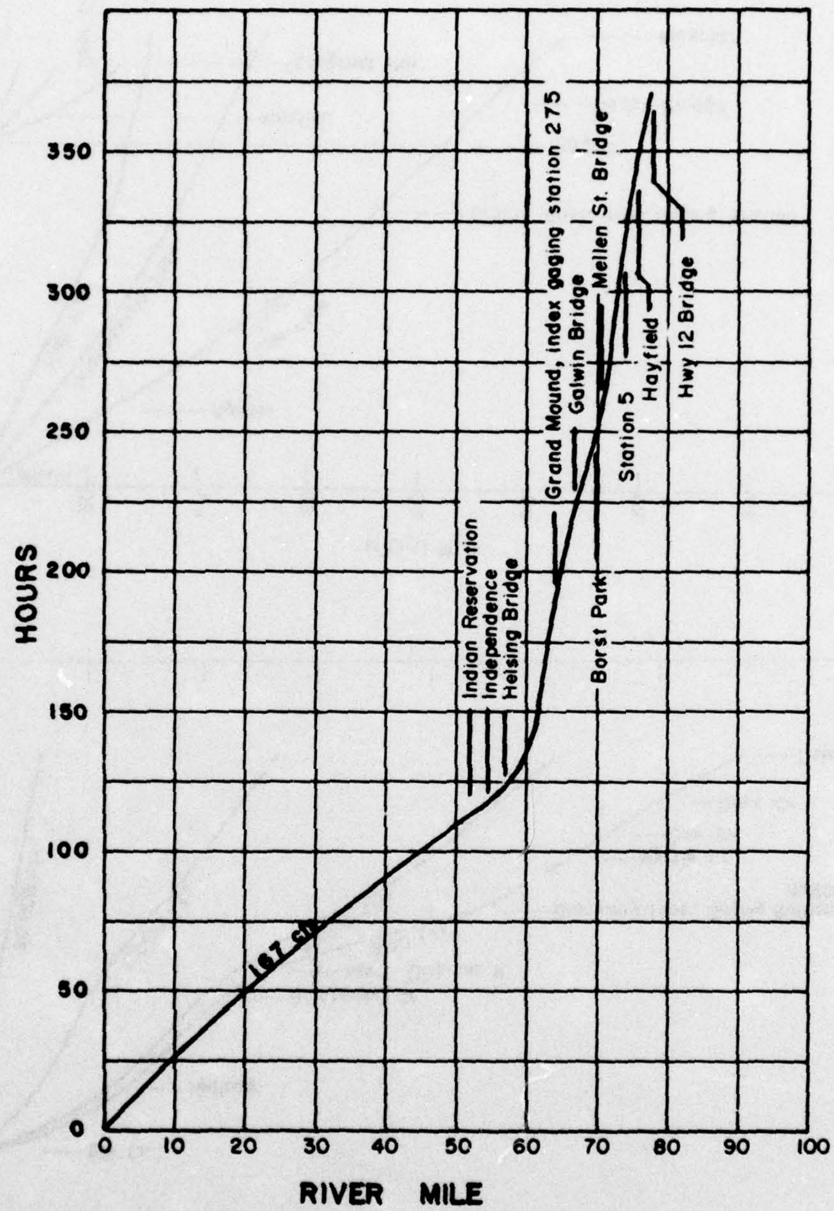


Figure 75i Time of travel, Chehalis River, for selected discharges at index gaging station

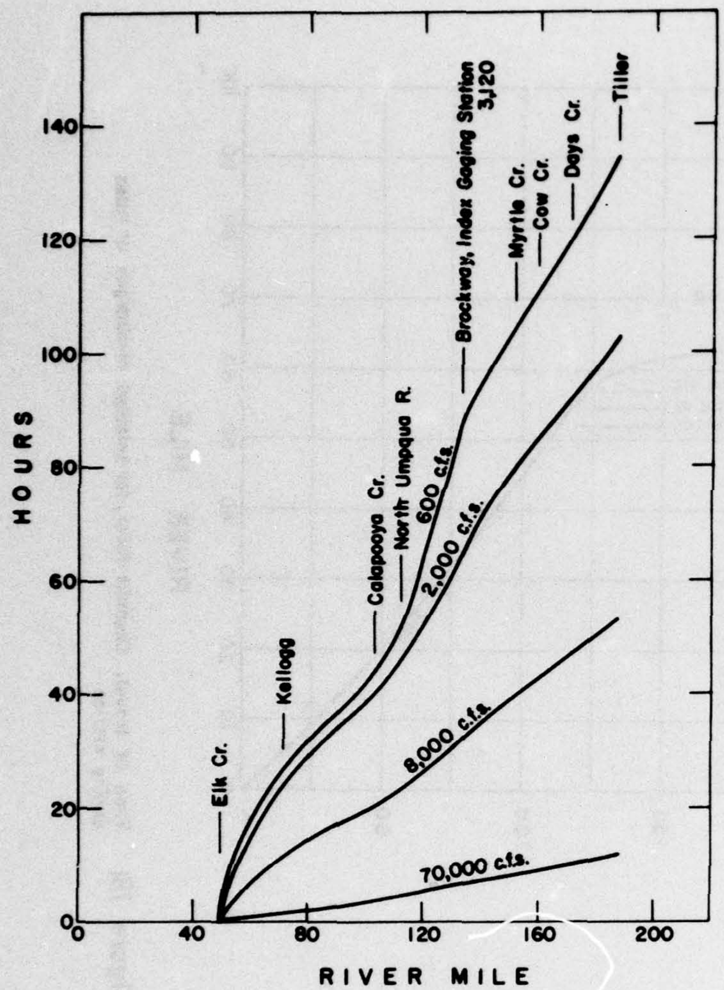


Figure 755 Time of Travel, Umpqua River, Oregon For Selected Discharges at Index Gaging Station

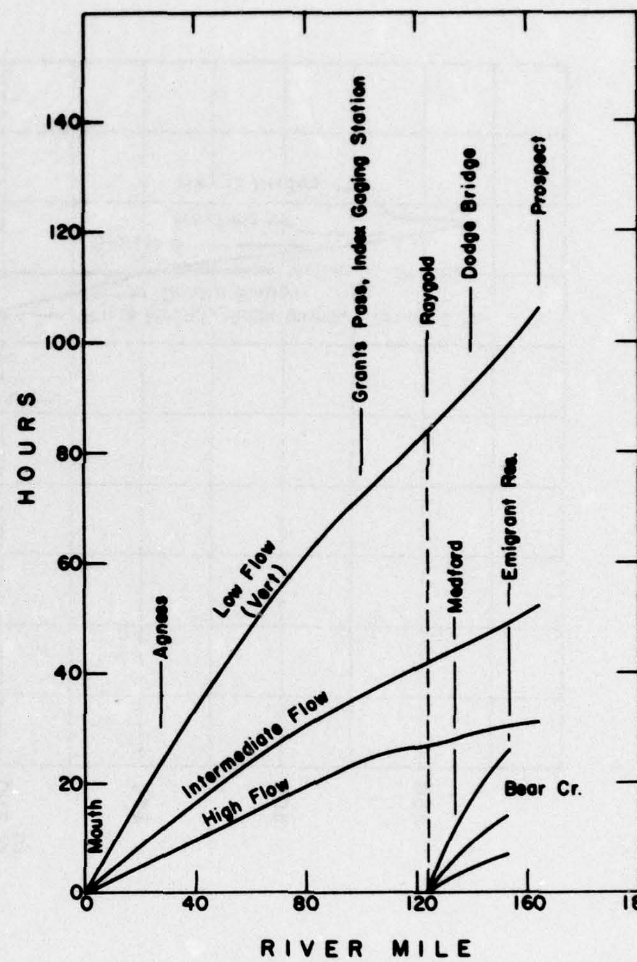


Figure 756 Time of Travel, Rogue River and Bear Creek For Selected Discharges at Index Gaging Station

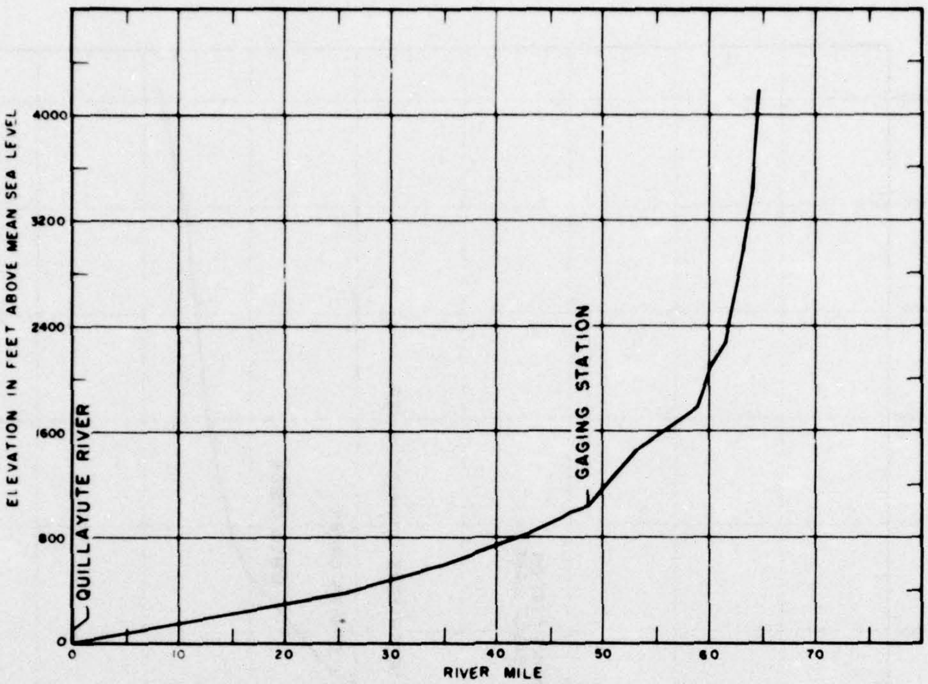


Figure 757 Stream Profile, Soleduck River, Washington

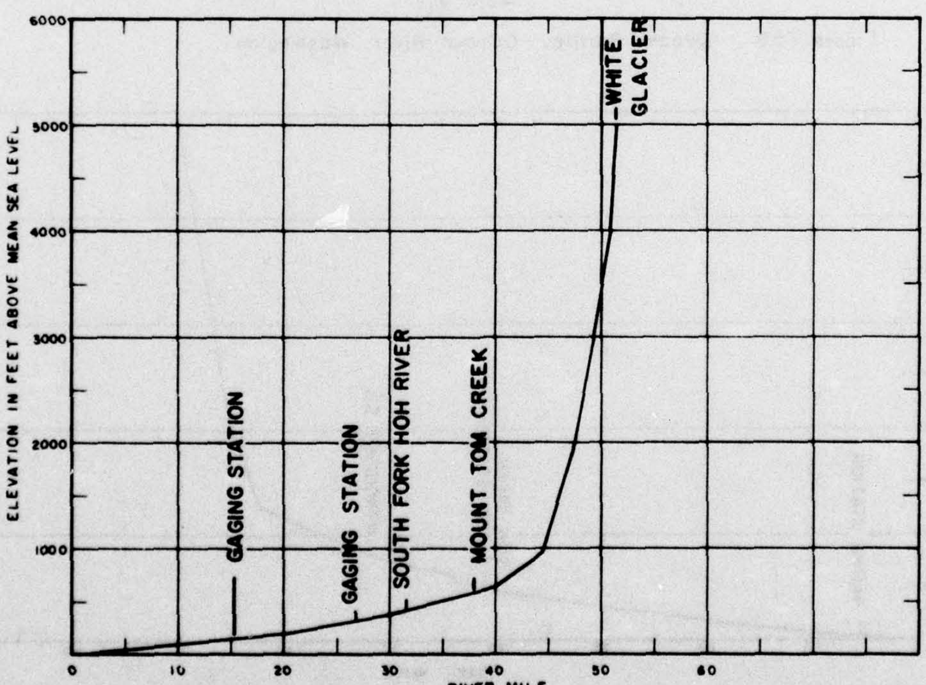


Figure 758 Stream Profile, Hoh River, Washington

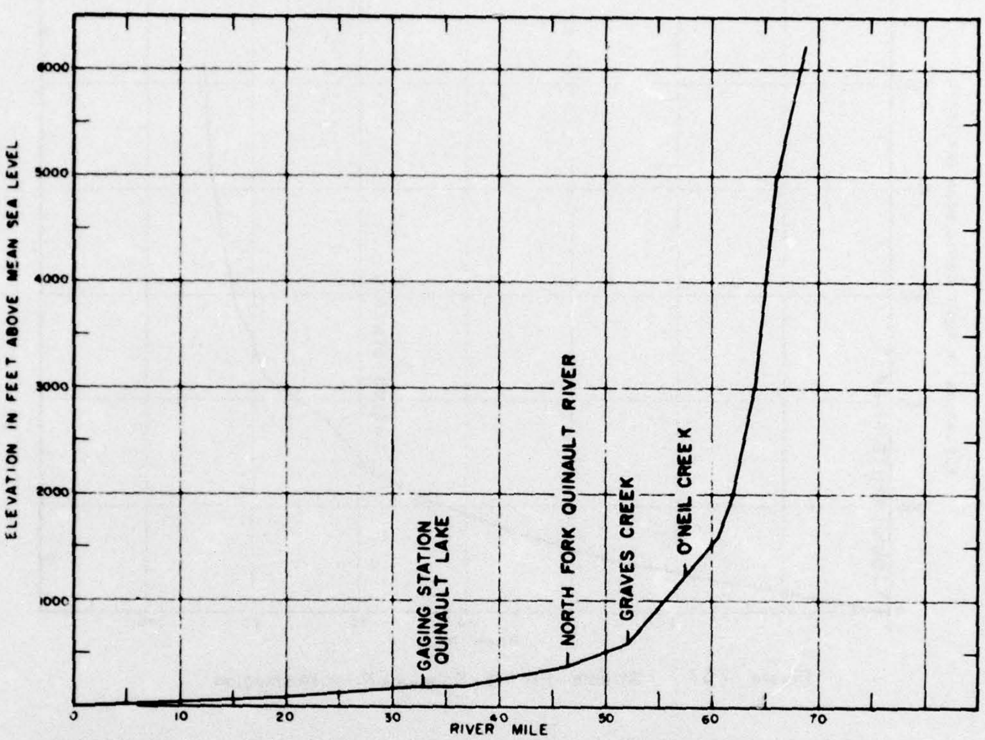


Figure 759 Stream Profile, Quinault River, Washington

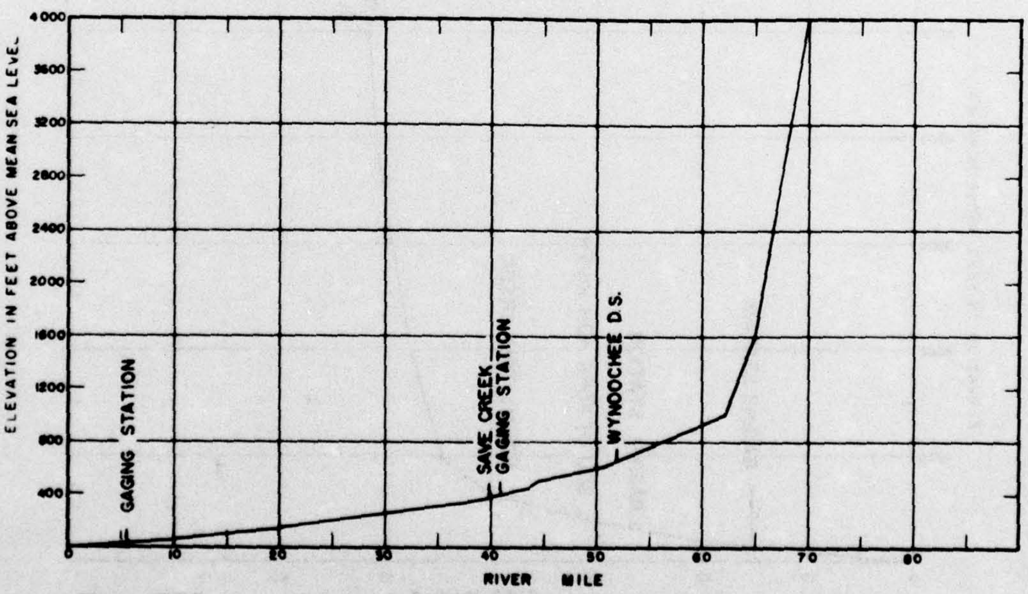


Figure 760 Stream Profile, Wynoochee River, Washington

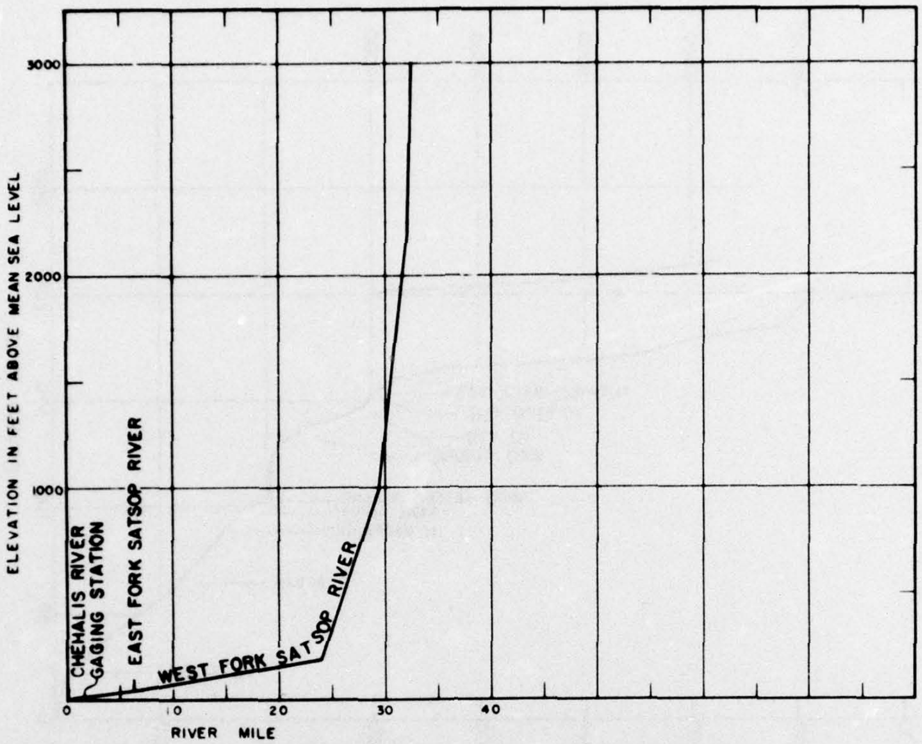


Figure 761 Stream Profile, Satsop River, Washington

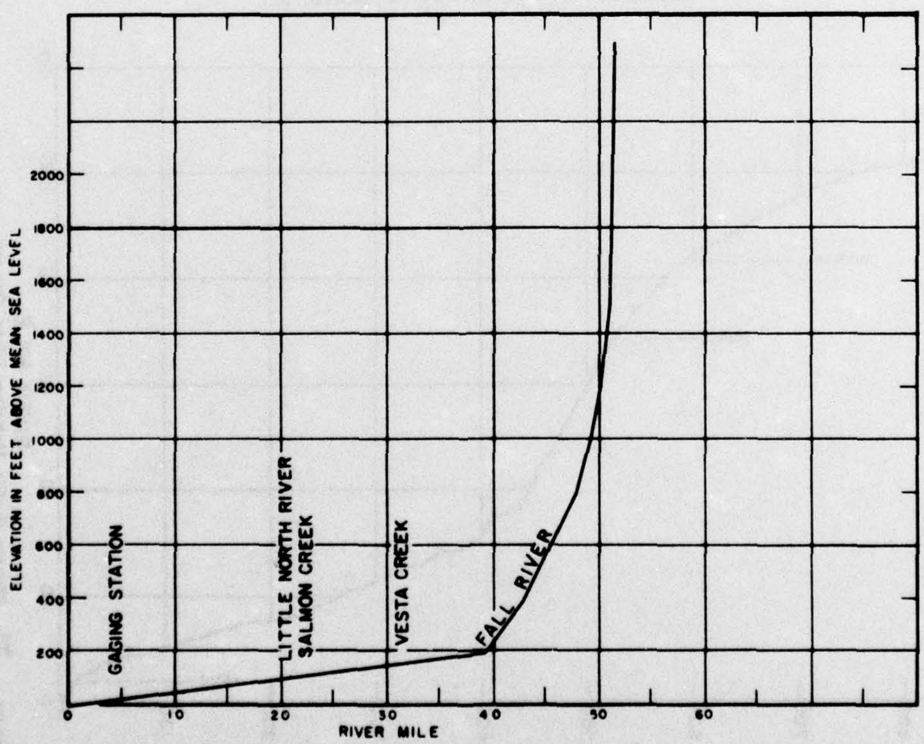


Figure 762 Stream Profile, North River, Washington

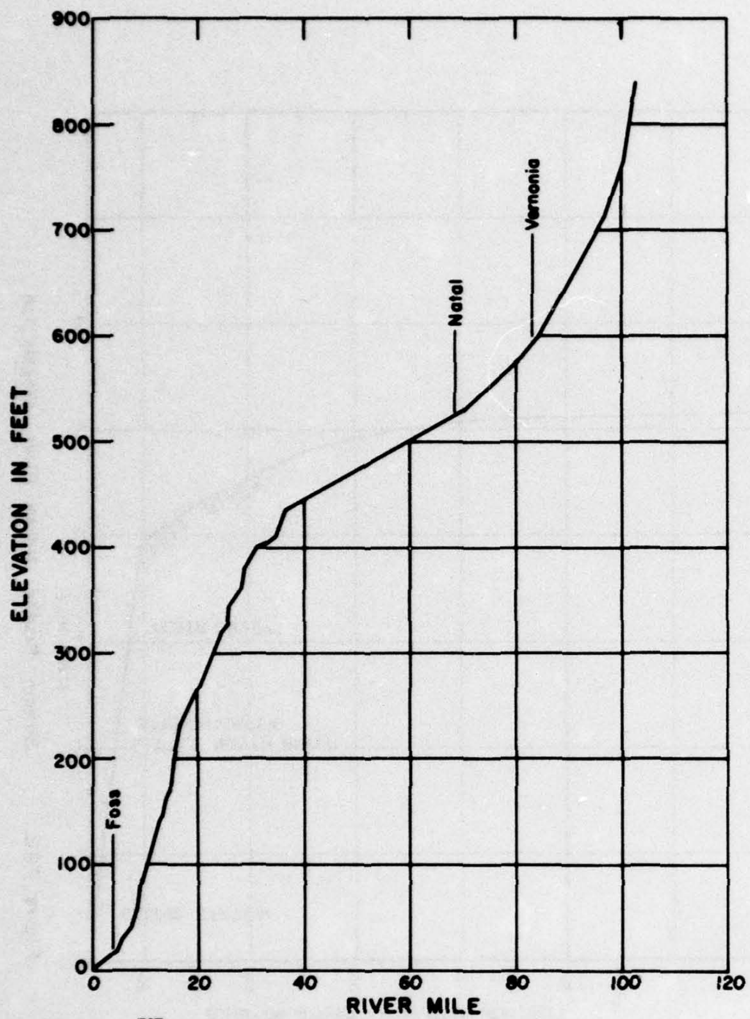


Figure 763 Stream Profile Nehalem River, Oregon

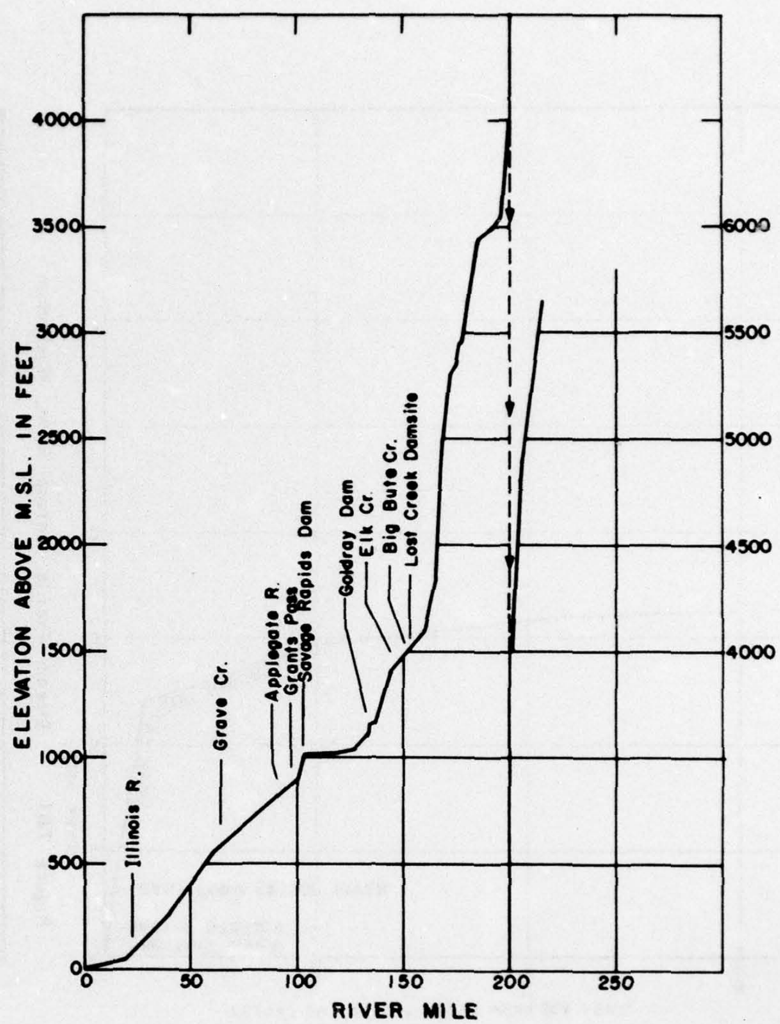


Figure 764 Stream Profile, Rogue River, Oregon

Quality

The quality of water in Subregion 10 is very good. Detailed information is presented on the following pages.

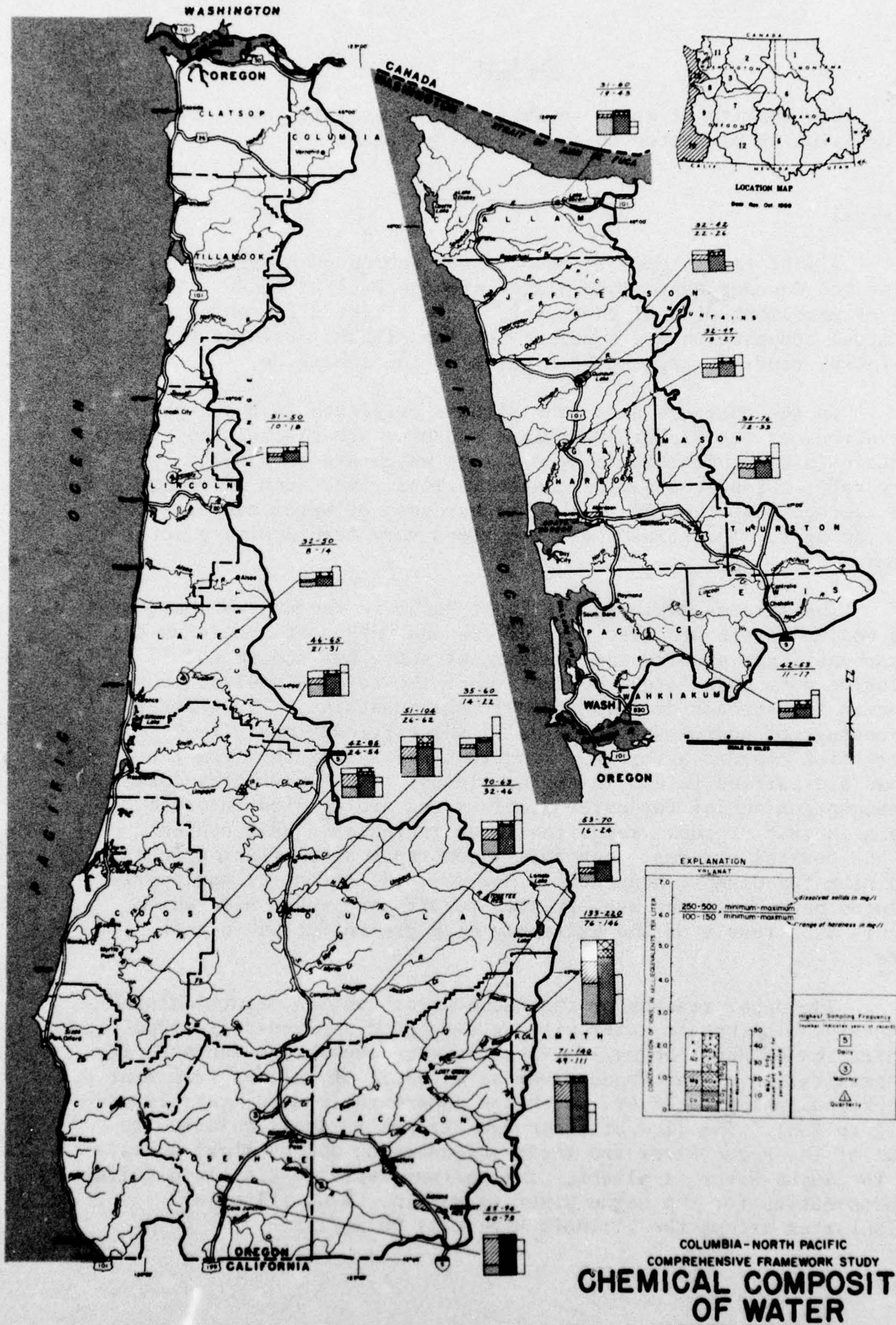
Chemical

All of the streams in the Coastal Subregion originate in the Coast and Cascade Ranges and drain into the Pacific Ocean. They are of excellent mineral character. Some slight differences in chemical composition are apparent between streams draining the northern, central, and southern parts of the subregion.

In the northern part, the streams originate in the high elevations of the Olympic Mountains and many are glacial fed. They contain calcium bicarbonate type waters which are very dilute and very soft. Dissolved-solids concentrations range from 30 to 60 mg/l and average less than 50 mg/l. The hardness of water averages less than 30 mg/l. The streams are sometimes very turbid with glacial flour.

The streams draining the Coast Range in the central part of the coastal basin are also very dilute and very soft. Calcium and bicarbonate are usually the predominant ions, but sodium and chloride make up a larger percentage of the total dissolved ions than in the streams draining the Olympic Mountains. The greater percentage of sodium and chloride in these streams most likely comes from oceanic aerosols. Windblown salt particles from the ocean are carried inland in fog or clouds. These particles form condensation nuclei for water droplets and are carried to earth again in rain or snow, resulting in an increase in salt content in the coastal streams. Aerosols undoubtedly also affect streams draining the Olympic Mountains. However, the effect is apparently diluted because of the much greater runoff per square mile which occurs as a result of the extremely high precipitation in that area.

The upper reaches of the Rogue River contain dilute calcium magnesium bicarbonate water with an average dissolved-solids concentration of about 60 mg/l. There is some downstream increase in mineralization of the Rogue River as a result of inflows from Bear Creek and Applegate River, which are considerably more mineralized (figure 765). The flow of these two streams is small relative to that of the Rogue River and their influence on the chemical quality of the Rogue River is slight. The maximum reported dissolved-solids concentration for the Rogue River at Merlin, below all major tributaries except the Illinois River, is 90 mg/l.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

COASTAL SUBREGION 10

1968

FIGURE 765

The Illinois River, tributary to the Rogue River, and South Fork Coquille River are considerably different in chemical character from all other streams in the subregion for which data are available. Both of these streams are magnesium bicarbonate waters. In the South Fork Coquille River the percentage of magnesium is only slightly higher than that of calcium. In the Illinois River, magnesium makes up an average 68 percent of the dissolved cations while calcium accounts for only 24 percent. Both of these streams drain areas in the Klamath Mountains which are underlain by igneous and metamorphic rocks that contain large amounts of the magnesium-rich minerals pyroxene and olivine.

All of the waters of the coastal subbasin are of excellent mineral quality, except in tide-affected reaches, and many could be used for most purposes with minimum treatment. High turbidity and color are a problem at certain times of the year, especially in the streams draining the Olympic Mountains. The lower reaches of most streams are affected by salt water intrusion. In many of the streams the rise in elevation is very slight for long distances upstream. In the Siuslaw River high chloride and sodium concentrations, indicative of salt water intrusion (and too large to be attributed to aerosol intrusion), have been found as far as 20 miles upstream from the mouth.

Biological-Biochemical

All streams on the Washington coast except the Chehalis River have high dissolved oxygen concentrations. On the Chehalis River, downstream from the city of Chehalis, dissolved oxygen levels drop to between 0 and 3 mg/l during the summer. This is a result of food processing and municipal waste loads on the slow moving low river flows. Grays Harbor estuary, at the mouth of the Chehalis River, exhibits dissolved oxygen values of less than 3 mg/l during late summer. This is attributed primarily to pulp mill wastes, although the estuary also receives substantial municipal and other industrial waste loadings. The oxygen deficit is occasionally intensified when deep ocean waters of low DO content (1 to 2 mg/l) are forced into the bay during the summer low flow period. Corrective measures have been requested by the State Water Pollution Control Commission and programs are underway to alleviate these dissolved oxygen deficiency problems.

The Chehalis River is again the only stream of less than excellent quality along the Washington coast. High total coliform densities are recorded below Chehalis and in the estuarial reaches of the river. Municipal wastes are the source.

The great majority of Oregon coastal streams exhibit high dissolved oxygen concentrations throughout their lengths. However, depressed oxygen levels do occur in several reaches of the Rogue and Umpqua Basins during low flow periods, with adverse effect on anadromous fish. Coos Bay experiences seasonal drops in dissolved oxygen levels to between 1 and 2 mg/l, to the detriment of aquatic life. To a lesser degree, Yaquina Bay also exhibits an oxygen depression during summer months.

Table 422 contains water quality information for streams of the subregion. Extensive information has also been collected by the states on estuaries, indicating a number of problem areas both with regard to oxygen levels and bacterial densities. Such estuarial data have not yet been summarized sufficiently for a brief presentation.

In several areas of the Oregon coast, bacterial concentrations resulting from untreated or inadequately disinfected sewage have reached levels which threaten health. Yaquina and Tillamook Bays now have bacterial conditions which have resulted in only "conditionally approved" oyster growing areas. The Public Health Service has stipulated that action to reduce coliform levels must be undertaken by 1968. To a lesser degree, problems also exist in Nehalem and Winchester Bays.

Sediment

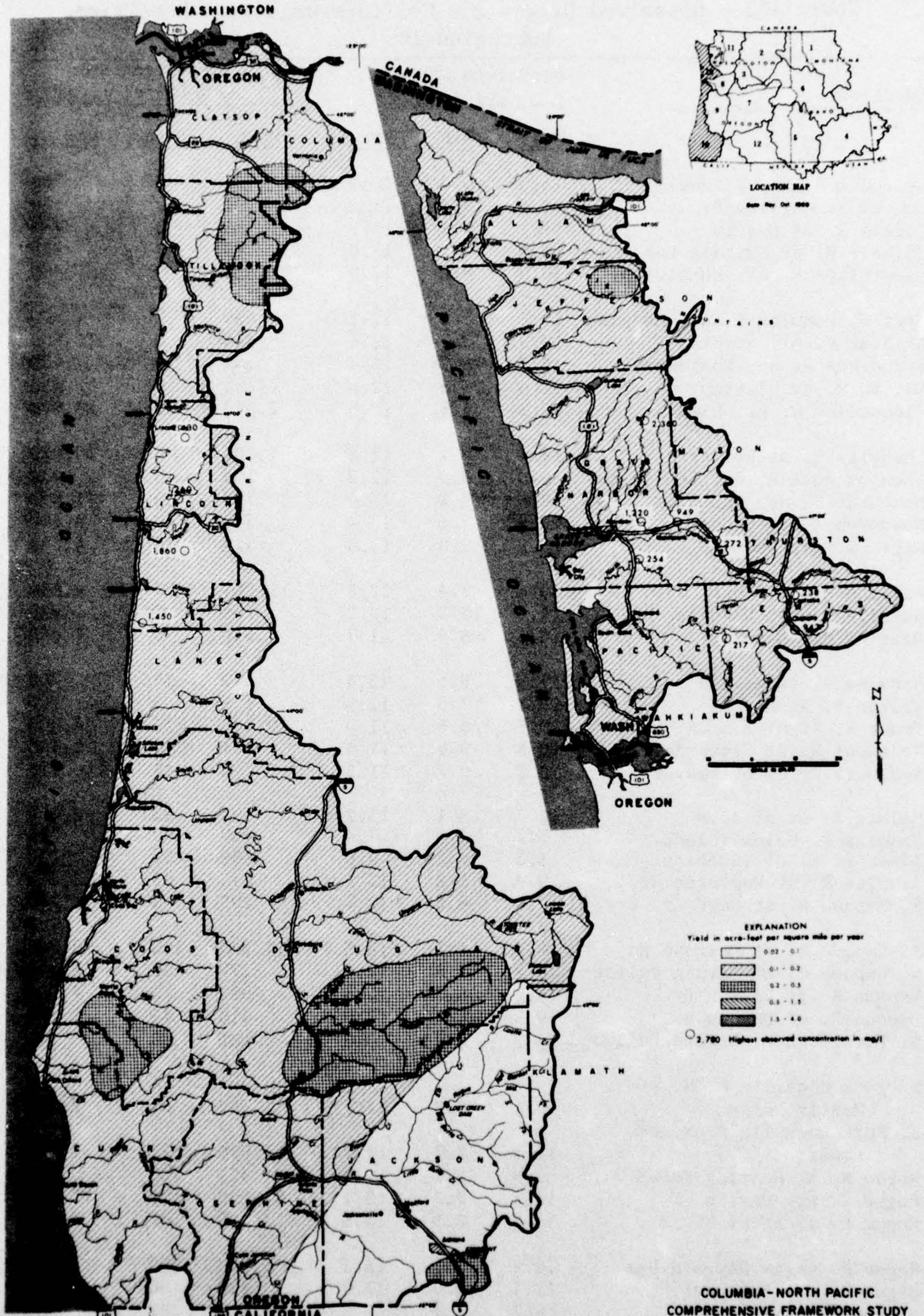
Suspended-sediment concentration has been measured at several locations in the Coastal Subregion; the earliest measurements were made in 1910-12. (17) The highest concentrations were observed since 1963, some of which are shown on figure 766. Studies have shown that road development associated with forest utilization and bank cutting along major streams were the main sources of suspended sediment. (30)

Figure 766 shows generalized sediment yield for the Coastal Subregion. (30) The yields range from 0.02 acre-foot per square mile per year in the upper reaches of the Rogue River Basin to 0.5 acre-foot per square mile per year, mostly in the agricultural areas, with about 80 percent of the subregion lying in the 0.1 to 0.2 range. Sediment production in the Coastal Subregion is generally low. There are few, if any, areas where extensive bank or gully erosion is occurring. This may be attributable to the quick recovery of vegetation, relatively thin soils, and the coarse texture of alluvial deposits which prevent substantial downcutting. (30)

Table 422 - Dissolved Oxygen and Coliform Organisms Densities, Subregion 10

Location	Dissolved Oxygen mg/l			Coliform Organisms MPN/100 ml		
	Mean	Min	Max	Mean	Min	Max
Soleduck R. nr. Fairholm	11.3	9.2	13.7	28	0	360
Hoh R. at Hwy 101 Br.	11.4	10.2	13.2	91	0	930
Queets R. at Queets	11.1	9.2	12.9	88	0	430
Quinalt R. at Quinalt Lake	10.6	9.2	13.0	19	0	230
Humptulips R. nr. Humptulips	10.9	9.0	12.9	78	0	430
West F. Hoquiam R. nr. Hoquiam	10.6	8.0	12.3	699	0	4,600
Wishkah R. nr. Wishkah	10.9	8.7	12.5	488	0	11,000
Wynoochee R. nr. Montesano	10.8	8.2	13.7	84	0	430
Satsop R. nr. Satsop	10.6	5.3	12.6	84	0	430
Cloquallum R. nr. Elma	10.5	4.8	12.5	2,840	36	24,000
Chehalis R. at Porter	10.4	7.2	12.8	1,209	0	24,000
Skookumchuck R. nr. Centralia	10.8	8.9	12.3	158	0	430
Newaukum R. nr. Chehalis	10.6	7.9	13.0	794	0	11,000
Newaukum R. at Chehalis	10.9	7.6	13.4	542	0	4,600
North R. nr. Raymond	10.9	9.0	12.0	919	36	4,600
Willapa R. at Lebam	10.6	8.4	12.8	751	0	4,600
Naselle R. nr. Naselle	11.3	10.2	12.2	268	0	930
Bear R. nr. Naselle	10.6	8.8	11.7	640	0	4,600
Nehalem R. at mi 7.3	11.0	8.6	13.4	315	13	700
Wilson R. at Hwy 6	10.8	7.3	12.9	108	5	700
Trask R. at mi 3.5 1/	9.7	8.5	11.0	10,540	620	24,000
Nestucca R. at Cloverdale	10.4	9.6	11.4	464	230	2,400
Nestucca R. E. of Beaver	10.3	9.2	11.3	92	45	210
Siletz R. at mi 30.9	10.7	8.1	13.2	394	23	2,400
Yaquina R. below Toledo 1/	5.2	4.0	7.4	460	60	700
Alsea R. E. of Tidewater	8.3	6.2	9.5	102	23	230
Siuslaw R. at Mapleton Br.	9.9	5.2	13.2	618	45	2,400
S. Umpqua R. at Days Cr. Br.	10.4	8.6	12.7	195	5	700
S. Umpqua R. at Melrose Rd.	10.3	6.3	12.3	13,270	450	70,000
N. Umpqua R. at Garden Valley	10.2	7.9	12.6	277	39	2,400
Umpqua R. at Elkton Br.	10.2	8.3	12.5	992	5	7,000
Umpqua R. at Umpqua Br.	9.9	8.1	12.6	415	45	1,300
S. Fork Coos R. beyond Dellwood 1/	8.2	6.9	9.5	181	62	240
N. Fork Coquille R. N. of Myrtle Point	9.1	6.0	12.7	562	60	2,400
S. Fork Coquille R. N. of Powers	11.1	8.7	14.1	2,996	23	7,000
Rogue R. at Huntley Park 1/	9.9	9.0	11.4	425	230	620
Rogue R. nr. Merlin	11.1	8.5	13.1	22,200	450	77,000
Rogue R. at Rocky Pt. Br.	11.1	8.3	13.5	3,182	130	22,400
Rogue R. below Raygold Dam	10.9	8.1	13.3	5,903	230	77,000
Rogue R. nr. Prospect	11.1	9.0	13.0	425	6	6,200
Chetco R. at mi 4.5 1/	8.2	7.9	8.5	108	23	240

1/ Less than four samples.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

COASTAL SUBREGION 10

1968

FIGURE 766

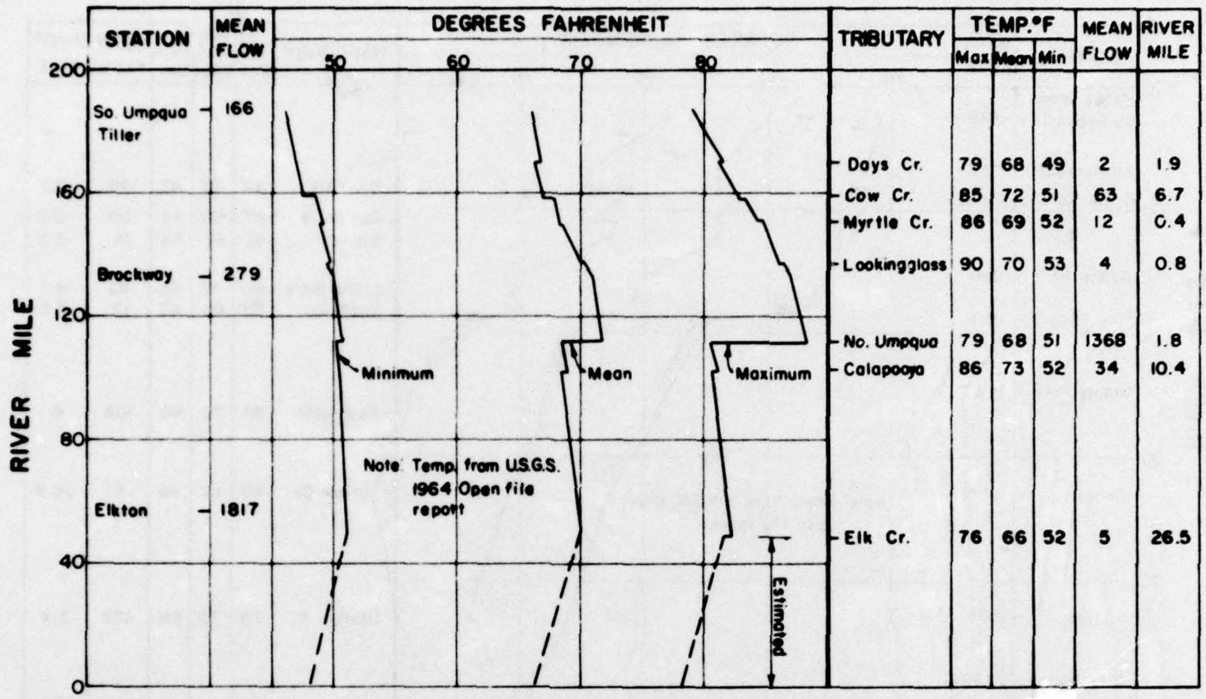


FIGURE 76[7] Water Temperature Profile for July, Umpqua River Basin, 1956-62

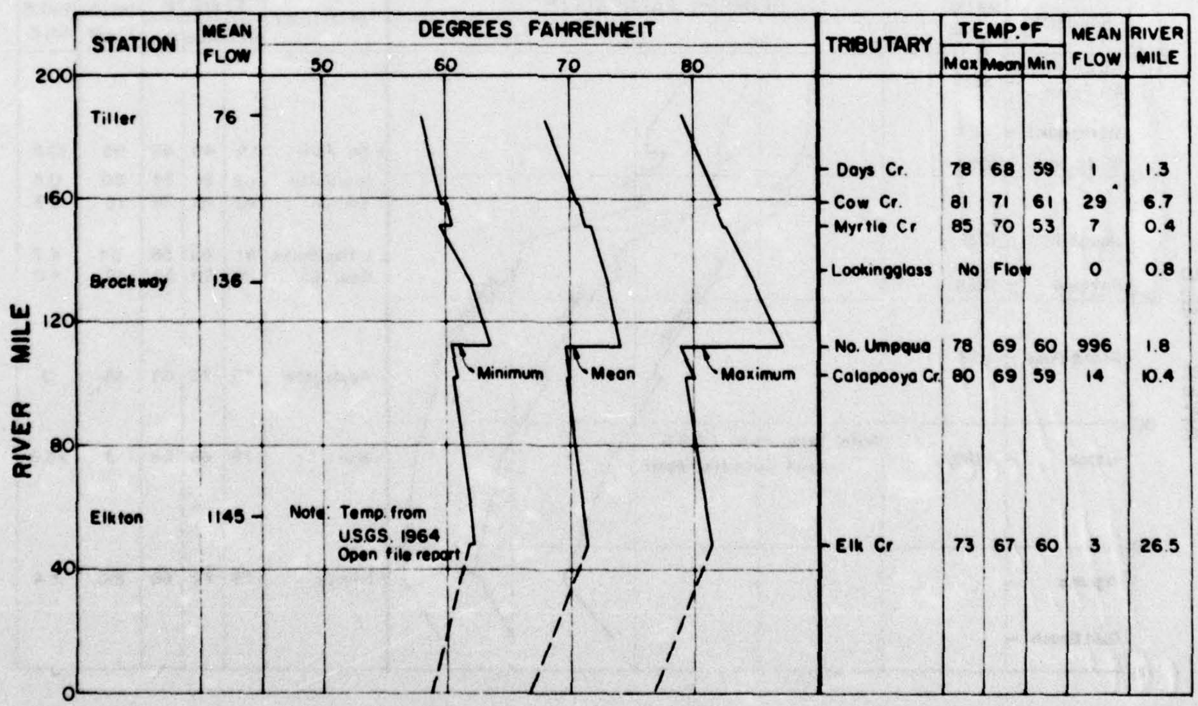


FIGURE 768. Water Temperature Profile for August, Umpqua River Basin, 1956-62

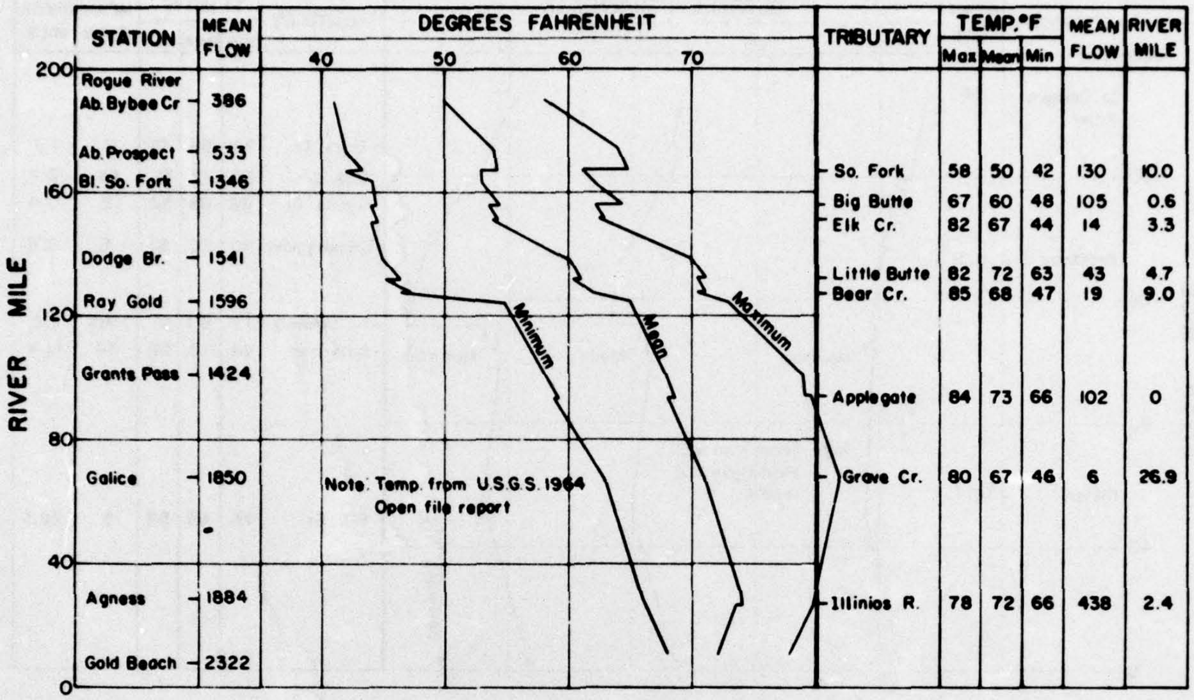


FIGURE 769. Water Temperature Profile for July, Rogue River Basin, 1947-62

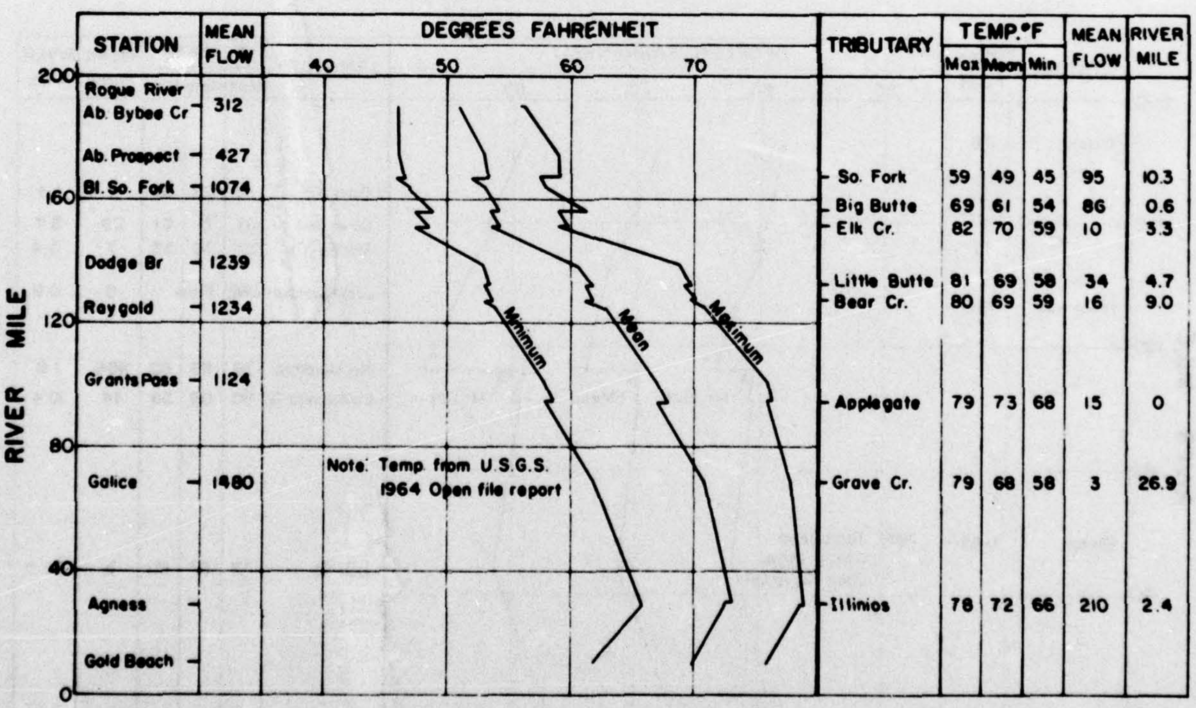


FIGURE 770. Water Temperature Profile for August, Rogue River Basin, 1947-62

Water Temperature

Water temperature profiles have been constructed for nearly 200 miles of the Umpqua and of the Rogue Rivers from 6 or 7 years of record. These profiles are for maximum, mean, and minimum temperatures for July and August. (figures 767 to 770) The temperatures of entering tributaries are also given, and their cooling effect on the main stem is clearly evident by the sharp drops in the profile.

Maximum temperature in the Umpqua River ranged from 79°F. to 88°F. during July and August. The range from minimum to maximum during the month was about 30°F. in July and 40°F. in August. Maximum temperatures in the Rogue River ranged from 56°F. to 82°F. during July and August. The range from minimum to maximum during the month was about 41°F. in July and 33°F. in August.

GROUND WATER

The alluvial deposits (Qal) are the most important source of ground-water supply for municipal, industrial, and irrigation use. However, these deposits are of limited extent and thousands of domestic and many small industrial and public supplies are obtained from other aquifers, most of which yield only small to moderate supplies.

Generally, the chemical quality of ground water is good to excellent for most uses. Dissolved solids are mostly less than 500 mg/l, and the water is soft to moderately hard. Water at depths of several hundred feet may be saline, and saline water has been encountered in marine sedimentary rocks (Tm) at depths of less than 100 feet. Excessive iron is found locally in ground water in the dune areas. Present use is only a small fraction of the total available supply. However, only in a few areas can wells with moderately large to large yields be developed.

Reports describing aquifers and ground-water occurrence have been published for only five small areas in Subregion 10. (11, 42, 95, 199, 200) Several other reports give some information. (106, 107, 109, 111, 114, 206)

Aquifer Units and Their Hydrologic Characteristics

Six aquifer units have been delineated in the Oregon part of the subregion and five in the Washington part. Aquifer-unit boundaries are shown on the map, figure 771, which is based on the geologic maps of Oregon (202) and Washington (54).

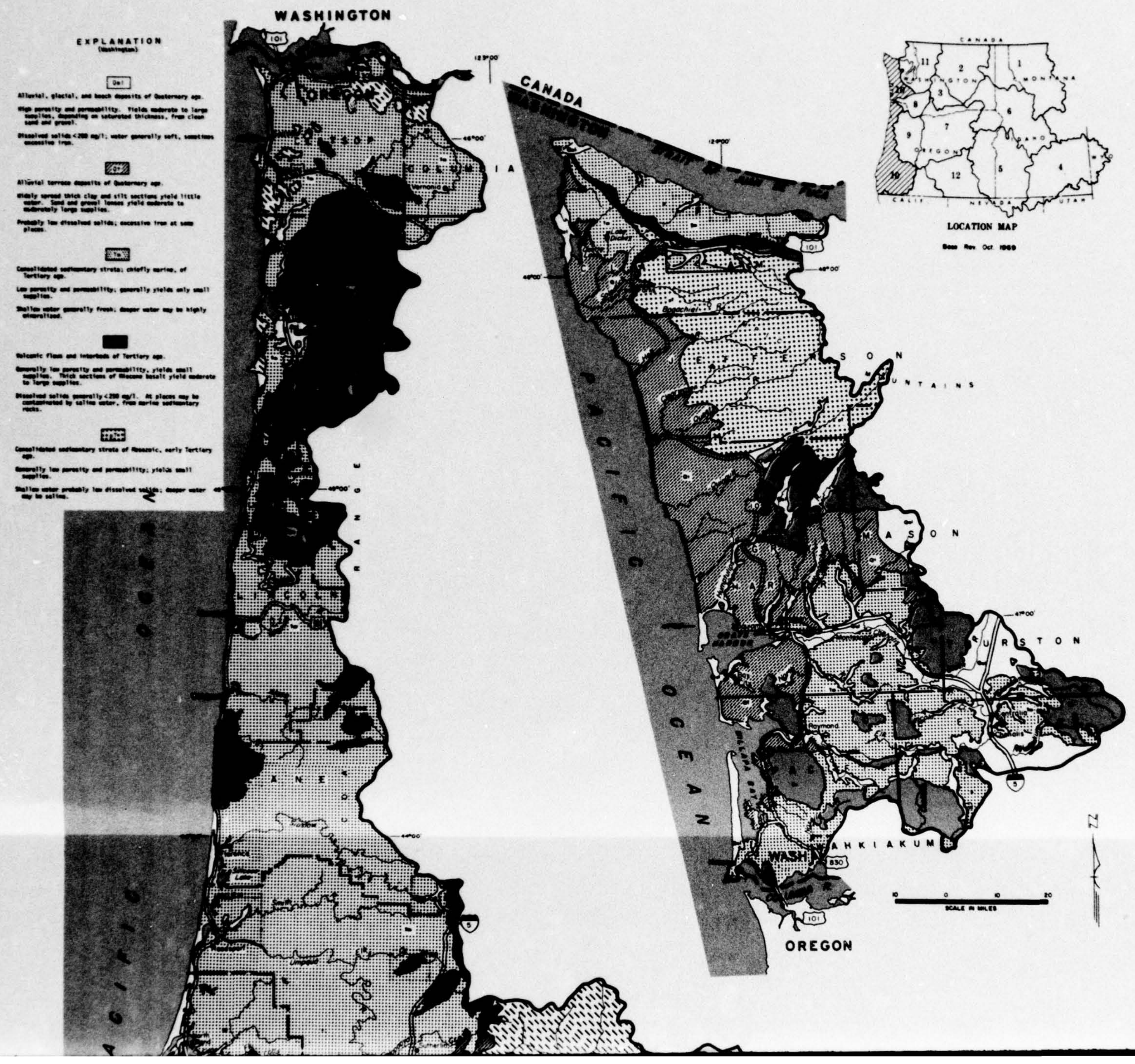
The alluvium deposits (Qal) are of three types: stream alluvial, glacial deposits, and beach deposits. The stream alluvium forms terrace and flood-plain deposits in the lower valleys. Most of the valleys are narrow and the deposits are generally less than 100 feet thick. Fine sand and silt predominate, but lenses of medium to coarse sand and gravel occur at many places and are good aquifers. Wells have moderate to moderately large yields and a few wells at favorable locations have large yields.

Glacial deposits occur in the Chehalis Valley north of Chehalis, in an area around Matlock, and in valleys along the north flank of the Olympic Mountains. There also may be some glacial outwash underlying, or interbedded with, alluvium in valleys on the west slope of the Olympic Mountains. The deposits include till, poorly sorted unstratified drift, and outwash. The till is almost impermeable and yields little water. The drift generally yields moderate supplies, and well-sorted outwash deposits yield moderately large to large quantities of water.

The dune and beach deposits underlie narrow coastal plains in several reaches along the Oregon and Washington coasts. They consist predominantly of very well-sorted, fine to medium-grained sand. Their thickness usually ranges from about 50 to 200 feet. They are very porous and moderately permeable, and yield moderate to moderately large supplies to properly constructed and developed wells.

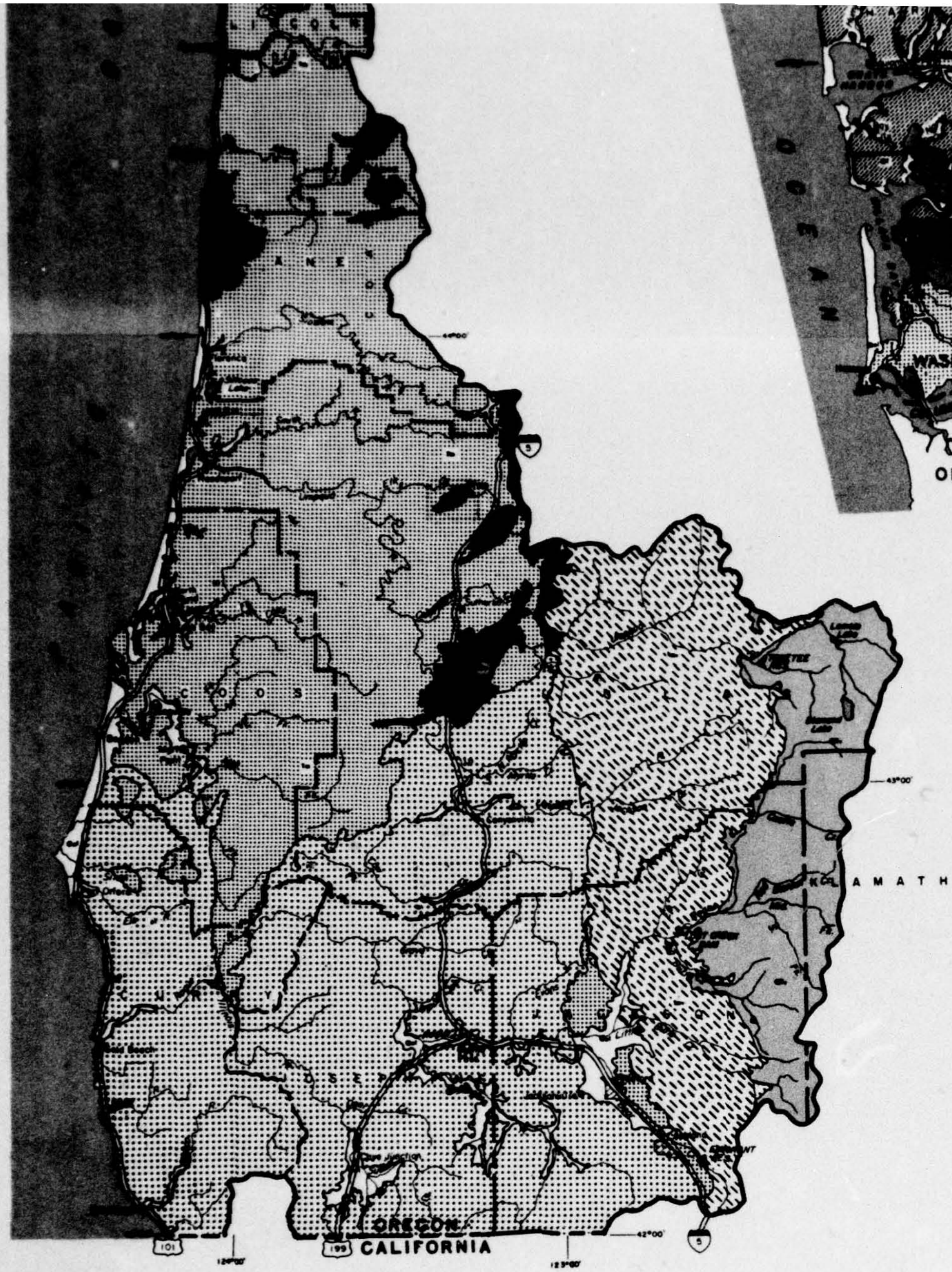
The terrace deposits of Quaternary age (Qt) occur largely in the Washington part of the subregion, where they underlie a low, broad terrace along the west and south flanks of the Olympic Mountains and the west side of the Coast Range. The deposits are predominantly fine-grained sand, silt, and clay and are believed to be largely of marine origin. However, lenses of medium to coarse sand and gravel are good aquifers and yield moderate to moderately large quantities of water at some places. Some of these aquifers may be alluvial deposits in former stream channels. The deposits are commonly deeply weathered. Similar marine terrace deposits in Oregon extend southward in a narrow band from North Bend to Port Orford. Because they are of such limited extent, they are included with the alluvial deposits (Qal) in the Oregon part of the subregion.

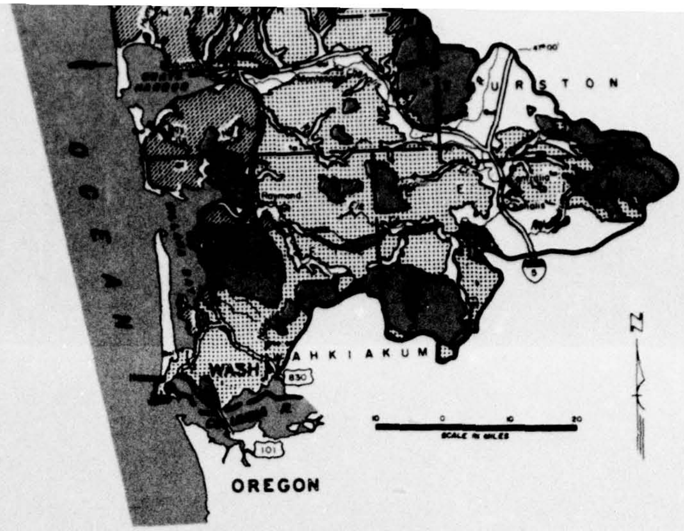
In Subregion 10 the younger volcanic rocks (QTv) crop out only in southern Oregon in the High Cascade Range. The volcanic rocks include open-textured basaltic to andesitic flows, breccia, agglomerate, scoria, pumice, and ash. Cinders, ash, and pumice are widespread at the surface. These materials are moderately to highly porous and permeable and are capable of yielding large quantities of water; however, they occur only at high altitudes in



EXPLANATION
(Washington)
Qal
Alluvial, glacial, and beach deposits of Quaternary age.
High porosity and permeability. Yields moderate to large supplies, depending on saturated thickness, from clean sand and gravel.
Dissolved solids <200 mg/l; water generally soft, sometimes excessive iron.
Qt
Alluvial terrace deposits of Quaternary age.
Widely spread thick clay and silt sections yield little water. Sand and gravel lenses yield moderate to moderately large supplies.
Probably low dissolved solids; excessive iron at some places.
Tm
Consolidated sedimentary strata; chiefly marine, of Tertiary age.
Low porosity and permeability; generally yields only small supplies.
Shallow water generally fresh; deeper water may be highly mineralized.
Volcanic flows and interbeds of Tertiary age.
Generally low porosity and permeability, yields small supplies. Thick sections of Miocene basalt yield moderate to large supplies.
Dissolved solids generally <250 mg/l. At places may be contaminated by saline water, from marine sedimentary rocks.
Consolidated sedimentary strata of Mesozoic, early Tertiary age.
Generally low porosity and permeability; yields small supplies.
Shallow water probably low dissolved solids; deeper water may be saline.
WASHINGTON
CANADA
PACIFIC OCEAN
MASON
THURSTON
WAHKIAKUM
WASH
OREGON
101
5
830
123°00'
124°00'
48°00'
47°00'
46°00'
RANGE
LOCATION MAP
Base Rev. Oct. 1969
CANADA
WASHINGTON
OREGON
MONTANA
IDAHO
NEVADA
UTAH
CALIF
SCALE IN MILES
10 0 10 20
N

2





EXPLANATION
(Oregon)

Qal

Alluvial and beach deposits of Quaternary age.

Yields moderate to large supplies of water, depending upon saturated thickness, from clean sand or sand and gravel.

Dissolved solids generally < 250 mg/l, water soft to moderately hard. Iron is a problem in many supplies.

QTv

Basaltic flows and pyroclastics of Quaternary and late Tertiary age.

Porous and permeable and is important reservoir in high Cascades. Capable of yielding moderate to large supplies.

Low dissolved solids, generally no hazardous constituents.

Tmv

Volcanic pyroclastics and flows of *Tertiary (chiefly Miocene) age.*

Low porosity, low to moderate permeability; yields small to moderate supplies.

Dissolved solids generally 500 mg/l. *Excessive boron, fluoride,* SAR in some wells.

Tm

Consolidated sedimentary strata, chiefly marine, of Tertiary age.

Low porosity and permeability, generally yields only small supplies.

Shallow water dissolved solids generally < 500 mg/l, boron, fluoride, SAR may be excessive. Deeper water may be highly *mineralized.*

Tov

Older volcanic rocks in the Coast Range, *of Tertiary age.*

Generally low porosity and permeability, yields only small supplies.

Dissolved solids generally low except where contaminated by saline water *from marine strata.*

pT

Sedimentary, igneous, and metamorphis rocks of pre-Tertiary age.

Generally very low porosity and permeability, yields only small supplies.

Dissolved solids generally < 500 mg/l; commonly excessive fluoride, boron, SAR.

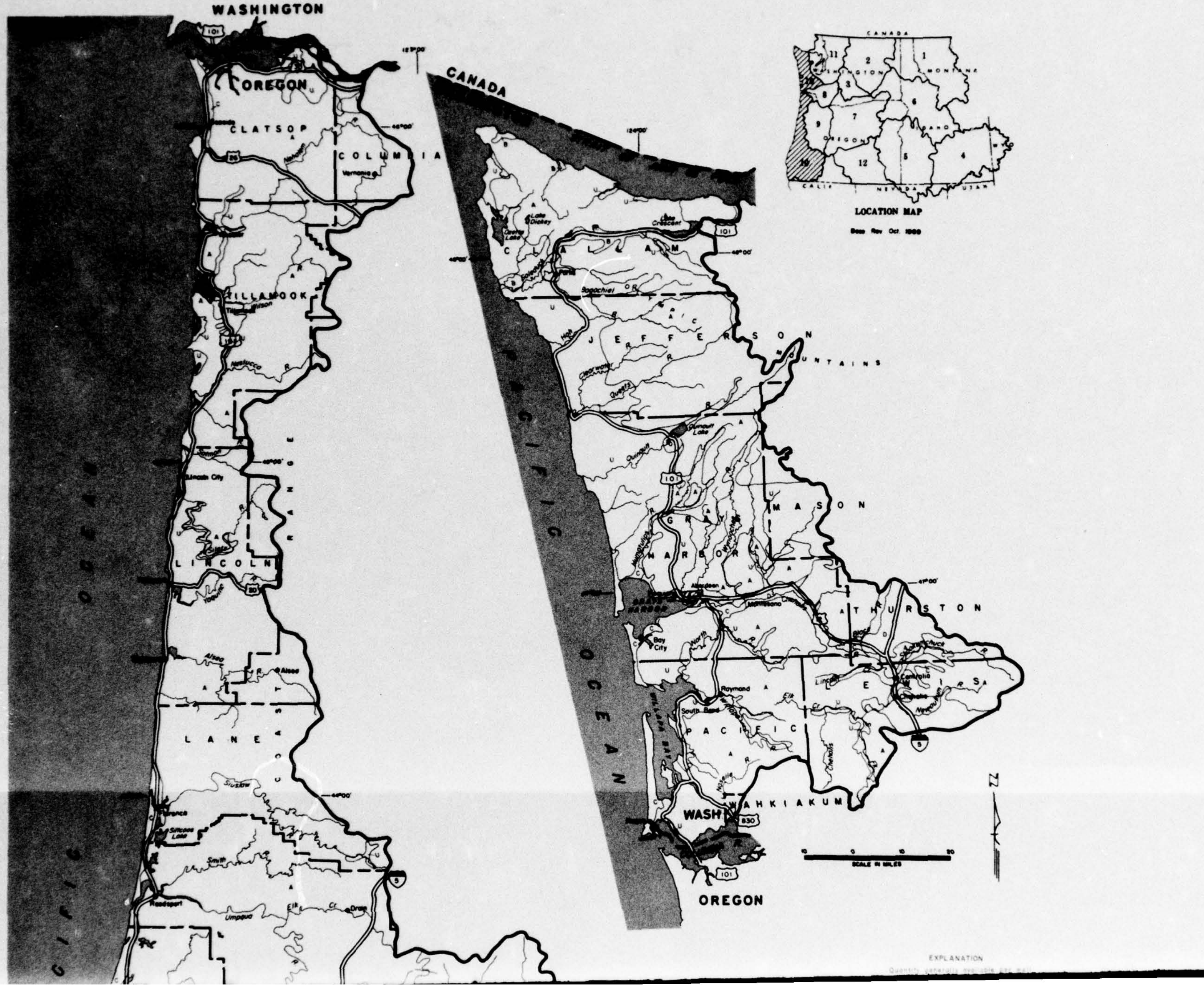
COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

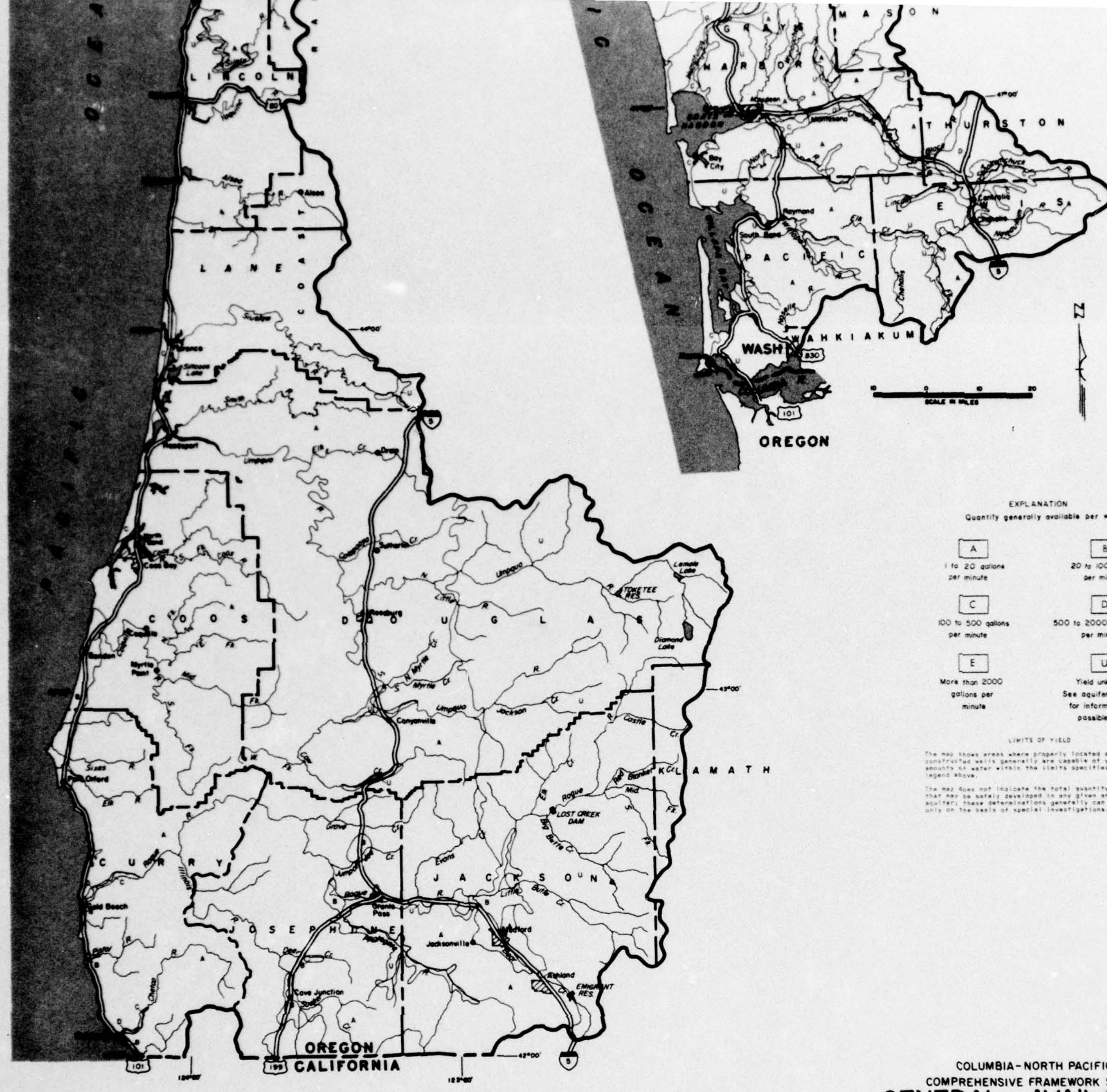
AQUIFER UNITS

COASTAL SUBREGION 10

1968

FIGURE 771


WASHINGTON
OREGON
CLATSOP
COLUMBIA
TILLAMOOK
LINCOLN
LANE
CANADA
CLALLAM
JEFFERSON
MASON
GRAYS HARBOR
THURSTON
PACIFIC
LEWIS
WAHKIAKUM
WASH
OREGON
PACIFIC OCEAN
WILLAPA BAY
LOCATION MAP
SCALE IN MILES
EXPLANATION



EXPLANATION

Quantity generally available per well

A — 1 to 20 gallons per minute	B — 20 to 100 gallons per minute
C — 100 to 500 gallons per minute	D — 500 to 2000 gallons per minute
E — More than 2000 gallons per minute	U — Yield unknown. See aquifer unit map for information on possible yields

LIMITS OF YIELD

The map shows areas where properly located and properly constructed wells generally are capable of yielding amounts of water within the limits specified in the legend above.

The map does not indicate the total quantity of water that may be safely developed in any given area or aquifer; these determinations generally can be made only on the basis of special investigations.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER

COASTAL SUBREGION 10

1968

FIGURE 772

2

sparsely inhabited areas. The water table may be far below land surface at many places; for example, north of Crater Lake the regional water table was not reached in a well drilled to a depth of 1,037 feet near the crest of the range. (45-7) Thin bodies of perched ground water were found in this well, and springs at relatively high altitudes at many places suggest that perched aquifers are common in the younger volcanic rocks (QTv). Ground-water effluent from the volcanic rocks is the major component of flow of streams draining these rocks.

The volcanic rocks of the western Cascade Range in Oregon (Tmv) include andesitic to basaltic flows, tuff, welded tuff, breccia, and agglomerate. Most of these are of Oligocene to lower Miocene age, but some Eocene, and Middle and Upper Miocene volcanic rocks are included. Basalt of the Columbia River Group in the Coast Range north of Nestucca River is also included in this unit. For the most part, the aquifer unit has moderately low porosity and permeability. The coarser-grained pyroclastic rocks and some interflow zones yield moderate or, rarely, moderately large quantities of water. Specific capacities of the wells commonly are 0.1 to 1.0 gpm per foot of drawdown. A thick, deeply weathered zone yields small to moderate supplies to dug and shallow drilled wells.

Sedimentary rocks of Tertiary age, chiefly of marine origin (Tm), crop out over extensive areas in the Coast Range of Oregon and Washington. Rocks are chiefly sandstone, shale, and mudstone, with lesser amounts of limestone and conglomerate. Lava flows and pyroclastic rocks are interbedded in the sedimentary strata at some places. Most of the rocks are of Eocene age but formations of Oligocene to Pliocene age are also included. For the most part, this aquifer unit has low to very low porosity and permeability and will yield only small supplies of water. Where the rock is greatly fractured, or the clastic rocks are coarser grained, moderate supplies are sometimes obtained from drilled wells. Most wells are less than 100 feet deep; only a small proportion of the wells exceed 200 feet in depth. Yields generally range from 1 to 20 gpm, rarely exceed 30 gpm. Specific capacities commonly are 0.05 to 1.0 gpm per foot of drawdown. About 5 percent of the wells are considered to be failures. Dug wells obtain small supplies from a comparatively thin zone of soil and subsoil. Water at depths of a few hundred feet is apt to be saline, especially where wells are drilled in synclines. At a few places saline water has been encountered at depths of less than 100 feet.

The older volcanic rocks (Tov) in Oregon and the volcanic rocks (Tv) in Washington are chiefly of Eocene age, but in Washington they include small areas of Miocene rock. For the most part they consist of basaltic to andesitic flows, flow-breccia,

pyroclastic rocks, and some interbedded sedimentary strata. The sedimentary interbeds commonly are tuffaceous. All of these rocks have been altered, mineralized, and cemented so that little of their original porosity remains. A thick, deeply weathered zone is considerably more porous but has moderately low permeability. The unweathered rock generally yields only very small supplies. Somewhat larger yields are obtained in the weathered material and in the broken rock at the base of the weathered zone. Most wells are less than 100 feet deep, and few are more than 150 feet deep. Well yields generally are between 1 and 20 gpm and specific capacities commonly range from 0.05 to 1.0 gpm per foot of drawdown. Five to 10 percent of the wells are considered to be failures.

The rocks of pre-Tertiary and early Tertiary (pT) age in the Olympic Mountains are mostly massive marine sedimentary rocks including graywacke, sandstone, shale, and some volcanic rocks. The unweathered rock has very low porosity and permeability and yields little water. A fairly thick weathered zone supplies a moderate base flow to streams. A large part of the outcrop area is uninhabited.

The pre-Tertiary (pT) rocks in southwestern Oregon crop out chiefly in the Klamath and Siskiyou Mountains. They include indurated and altered mudstone, siltstone, graywacke, and andesitic volcanic rocks; gneiss, schist, and greenstone; and intrusive igneous rocks ranging from granite to peridotite and serpentine. The unweathered phase of all of these rocks has low to very low porosity and permeability. A weathered zone of varying characteristics has developed on them. On the fine-grained sedimentary and some of the metamorphic rocks, the weathered zone is shallow and clayey so that specific yield and permeability are very low. The igneous rocks, particularly the granite, have a thicker weathered zone that has somewhat higher specific yield and permeability; moderate yields are obtained from dug or shallow drilled wells at favorable locations.

A summary description of aquifer units, their general hydrologic characteristics, and the quality of water yielded by them are given in tables 423 and 424. The availability of ground water is shown on a map, figure 772. For maximum utility that map and the aquifer-unit map, figure 771, should be used together.

Table 423 - Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 10 (Oregon Part)

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qal: Alluvial deposits formed along streams, in estuaries, and along beaches. Includes beach dunes and marine terrace deposits. Quaternary in age.	Unconsolidated to slightly consolidated clay, silt, sand, and gravel. Alluvial deposits along streams generally moderately well sorted, contain lenses of clean sand and gravel.	Clean, well sorted sand and gravel are porous and permeable. Yields depend on thickness of these strata encountered. Fine-grained sand generally yield up to 200 gpm. Coarser grained deposits yield 500 to 1,000 gpm where 50 to 100 feet of permeable strata are saturated.	Dissolved solids generally less than 250 mg/l, rarely more than 500 mg/l. Water generally soft to moderately hard. Iron is a problem in many supplies.
QTv: Volcanic rocks of the High Cascades, chiefly basaltic. Pliocene to Holocene in age.	Chiefly basaltic to andesitic open-textured flows, breccia, tuff breccia, agglomerate forming lava domes, cones, and intercanyon flows; coarsely granular ash, pumice deposits, and scoria.	Rocks are moderately porous and highly permeable. Accept, store, and transmit large quantities of water, maintaining base flow of streams. Few wells drilled in unit because it occurs chiefly in mountains. Large yields possible. Water table many hundred feet below surface in some areas.	The few data available show dissolved solids generally less than 100 mg/l; fluoride, boron low, iron excessive in some samples.
Twv: Volcanic, pyroclastic, and flow rocks of the Western Cascade Range and basalt of the Columbia River Group in the Coast Range. Mostly Oligocene to Miocene in age.	Stratified to poorly bedded and massive tuff, welded tuff, and breccia. Pyroclastic rocks commonly light colored, andesitic. Flows include andesite, andesitic basalt, and basalt. Alteration common; zeolite filling in vesicles and other openings.	Moderately low porosity and permeability. Coarser, less cemented pyroclastic rocks and interflow zones yield small to moderate supplies of water. Yields of domestic wells generally 5 to 20 gpm; specific capacities 0.1 to 1.0 gpm per foot of drawdown. Moderately low base flow to streams.	Few data available indicate dissolved solids generally less than 500 mg/l. Water soft to moderately hard. Excessive fluoride, boron, in some samples. Sodium adsorption ratio may exceed 10.
Tm: Stratified, chiefly marine sedimentary rocks of the Coast Range. Eocene to Pliocene in age.	Shale, sandstone, mudstone, and limestone, some conglomerate and coal beds. Clastic rocks characteristically are tuffaceous. Thin bedded to massive.	Little original porosity remains because of compaction, cementation, alteration. Water occurs in joints, fractures, and residual original porosity in coarser-grained rocks. Yields generally small, rarely moderate. Supplies low base flow to streams.	Water at depths of less than 150 feet generally has dissolved solids less than 500 mg/l; deeper water generally more saline, may be highly saline. Water soft to hard.
Tov: Older volcanic rocks of the Coast Range. Chiefly Eocene in age. Includes Tertiary intrusive rocks.	Interbedded basalt and andesite flows and pyroclastic rocks. Commonly greatly altered, vesicles and other openings filled with secondary mineralization products.	Generally low porosity and permeability. Well yields are generally small, rarely moderate. Weathered zone supplies moderately low to moderate base flow to streams.	Dissolved solids generally low except where contaminated by mineralized water from marine sedimentary deposits.
pT: Pre-Tertiary rocks. Paleozoic-Mesozoic sedimentary, metamorphic and intrusive complex in the Klamath Mountains of southwest Oregon.	Mudstone, siltstone, graywacke, and andesitic volcanic rocks; mostly greatly altered, with slaty cleavage; gneiss, schist, greenstone; intrusive rocks ranging from granite and diorite to peridotite and serpentine.	Generally low porosity and very low permeability. Domestic well yields generally less than 10 gpm; perhaps 25 percent less than 1 gpm. Low base flow to streams.	Dissolved solids generally less than 500 mg/l; water ranges from very soft to very hard.

Table 424. - Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 10 (Washington Part)

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qal: Southwest of Olympic Mountains and on west flank of Coast Range; chiefly stream alluvium and beach deposits. North flank of Olympic Mountains and upper Chehalis River chiefly glacial deposits. Quaternary in age.	Unconsolidated deposits ranging from coarse, clean sand and gravel to fine-grained silt and clay and glacial till. In lower reaches of streams material generally is fine grained. Beach deposits range from lagoonal muds and silts to clean, fine- to medium-grained sand.	Porosity and permeability of well-sorted coarser deposits are high. Glacial outwash, fluvial sand and gravel yield large supplies. Finer-grained alluvium along lower courses of rivers has low permeability. Beach sands are moderately permeable and generally yield moderate to moderately large supplies.	Dissolved solids less than 200 mg/l; water generally soft, occasionally moderately hard. Fluoride low, sometimes excessive iron.
Qt: Terrace deposits on west flank of Olympic Mountains and the Coast Range. In part of marine origin. Probably early to Middle Pleistocene in age.	Unconsolidated to partly consolidated sand, gravel, silt, and clay. Deposits commonly deeply weathered, brown to red color. Thick sections of clay and silt in some places.	Deposits are porous and contain large quantities of water in storage but permeability varies greatly. Well sorted, unweathered sand and gravel yield moderate to large supplies of water, but at many places permeability is greatly reduced by deep weathering.	Few data available; probably similar to water in Qal.
Tm: Stratified sedimentary rocks, chiefly marine, folded and faulted, forming hills and mountains. Chiefly Eocene to Miocene in age. Some Pliocene in age.	Massive to thin-bedded consolidated sandstone, siltstone, shale; some conglomerate and coal beds. Many beds are partly or largely of tuffaceous or other volcanic material.	Generally low porosity and permeability but deeply weathered zone supplies moderate base flow to streams. Few data available but well yields probably in the range of 1 to 20 gpm for the most part. (See description in Oregon section of subregion.)	No data available. Probably similar to Ts in subregion 10 (Oregon) where shallow water is generally fresh, deeper water may be saline.
Tv: Volcanic rocks of Eocene age flanking the Olympic Mountains. Eocene and Miocene in age in the Coast Range. Miocene volcanic rocks may be equivalent in part to the Columbia River Group.	Basalt flows and breccia including pillow lava and amygdaloidal and vesicular flows. Includes some interbedded pyroclastic rocks and sedimentary strata.	Moderately low to low porosity and permeability. Deeply weathered zone supplies moderate base flow to streams. Wells generally yield 1 to 20 gpm. Miocene basalt between Longview and Cathlamet is thicker and some wells yield larger quantities.	Dissolved solids less than 250 mg/l. Water soft to moderately hard.
pT: Sedimentary rocks, chiefly of marine origin, of the central Olympic Mountains complex; chiefly Mesozoic and Paleocene or early Eocene in age.	Dark gray, massive to poorly bedded graywacke; interbeds of shale, argillite, arkosic sandstone, and some altered lava flows and other volcanic rocks.	Generally low porosity and permeability, except for deeply weathered zone which supplies a moderate to good base flow to streams. No data available on well yields.	No data available but shallow ground water probably low dissolved solids, soft. Deeper water may be saline, mineralized.

Water in Storage

A rough estimate of the quantity of water stored in each aquifer unit within the uppermost 50 feet below the water table is given in table 425.

A specific yield of 20 percent was used for the alluvium (Qal) and 5 percent for the younger volcanic rocks (QTv). The terrace deposits (Qt) probably have high porosity, but because they are predominantly fine-grained, the specific yield is considerably less than the porosity; a specific yield of 10 percent was used for that unit. For the most part, the unweathered rock of all other aquifer units has low porosity. However, a fairly deep to very deep weathered zone is more porous. Because the soil and subsoil on the sedimentary rocks (Tm) generally is thinner than on other rock units, a specific yield of 1 percent was used for that unit. An average value of 2 percent was assumed for the upper 50 feet of saturation for all other aquifer units (Tmv, Tv, Tov, pT). According to table 425, about 14 million acre-feet of water in Oregon and about 13 million in Washington are stored in the uppermost 50 feet of the saturated zone. In Oregon, about 45 percent of the total is in the alluvial deposits (Qal) and younger volcanic rocks (QTv). In Washington, more than 45 percent of the total is stored in the alluvial deposits (Qal) and about 40 percent in the terrace deposits (Qt).

Natural Recharge and Discharge

With few exceptions, average annual precipitation in the subregion is high, ranging generally from 60 to more than 120 inches. A few interior valleys receive less than 30 inches; a small area in the Oregon Coast Range and a large area in the Olympic Mountains receive more than 200 inches. Most of the precipitation occurs as rainfall during the late fall, winter, and spring. Recharge is almost entirely by direct rainfall on the areas of outcrop of the aquifer. About 80 percent of the subregion is underlain by aquifer units (Tmv, Tv, Tm, Tov, pT) whose specific yields are estimated to be about 2 percent or less. With the combination of low specific yield and heavy rainfall, the water table rises rapidly and comes quickly to a level where ground water discharges into even the most minor of drainage channels in the rugged terrain. Generally, the water level in those aquifers reaches a peak in early winter or midwinter; thereafter, continued heavy precipitation merely maintains the water table at relatively high levels. During periods of a week or two without rainfall, the water table declines sharply. Considerable potential recharge probably is rejected in late winter and spring. At some places in the western Cascade Range, permeable horizons occur in the volcanic rocks at depths

Table 425 - Storage, Recharge, and Discharge of Ground Water in Aquifer Units in Subregion 10, 1970

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge	
	Sq. Mi.	Acres (1000's)	Specific Yield (Percent)	Depth Used (Ft)	Water (1000's ac-ft)	Inches Over Area	(1,000's ac-ft)
Oregon							
Qal	710	455	20	50	4,550	36	1,360
QTv	1,180	755	5	50	1,900	24	1,500
Tmv	2,400	1,540	2	50	1,540	6	770
Tm	6,340	4,050	1	50	2,000	12	4,050
Tov	1,600	1,020	2	50	1,020	12	1,020
pT	4,930	3,160	2	50	3,160	4	1,050
Sub-total (rounded)	17,160	10,980			14,000		10,000
Washington							
Qal	970	620	20	50	6,200	42	2,170
Qt	1,680	1,070	10	50	5,350	18	1,600
Tv	900	575	2	50	575	12	575
Tm	1,650	1,050	1	50	500	12	1,050
pT	1,180	755	2	50	750	6	380
Sub-total (rounded)	6,380	4,070			13,000		6,000
TOTAL (rounded)	23,500	15,050			27,000		16,000

ranging from near surface to many hundred feet. Subsurface discharge outlets for the deeper aquifers may be at altitudes much below the general upland surfaces causing water levels in successively deeper aquifers to be at progressively lower levels. Recharge to these deeper aquifers is by downward leakage from near-surface aquifers. Because of the storing and delaying effect of the overlying aquifers, recharge to the deeper horizons is continuous and fluctuations of the water table in the deeper aquifers are small. Some of these deeper aquifers are not really extensive, and because recharge is restricted by overlying materials of low permeability, withdrawal of moderate to moderately large supplies from several wells in the same area and aquifer may cause significant declines in the water table.

For the most part, water levels in the alluvial deposits (Qal) also reach near maximum levels by midwinter; however, they are much more porous and permeable and probably reject little recharge. The younger volcanic rocks (QTv) occur in the High Cascade Range; much of their recharge is from snowmelt in the spring, and that unit probably rarely rejects recharge. Hydrographs of representative wells are shown in figure 773.

Almost everywhere ground water is effluent to streams throughout the year. Some reaches of streams in the younger volcanic rocks may lose water where they cross particularly porous materials but they gain large quantities of ground-water discharge in reaches upstream from the volcanic rocks (Tmv) of the western Cascade Range. Short reaches of some lowland streams may temporarily lose water to bank storage.

Rough estimates of average annual recharge and discharge are given in table 425. These estimates are based on analysis of the ground-water component of discharge of selected streams, taking into account the considerable differences in average annual precipitation on the areas of outcrop of the various aquifer units. Average annual recharge to and discharge from aquifer units in the Oregon part of the subregion is about 10 million acre-feet, about 40 percent from the consolidated Tertiary sedimentary rocks (Tm) and about 15 percent each from the alluvial deposits (Qal) and the younger volcanic rocks (QTv). In the Washington part of the subregion, natural recharge and discharge is about 6 million acre-feet; about two-thirds is from the alluvial (Qal) and terrace deposits (Qt).

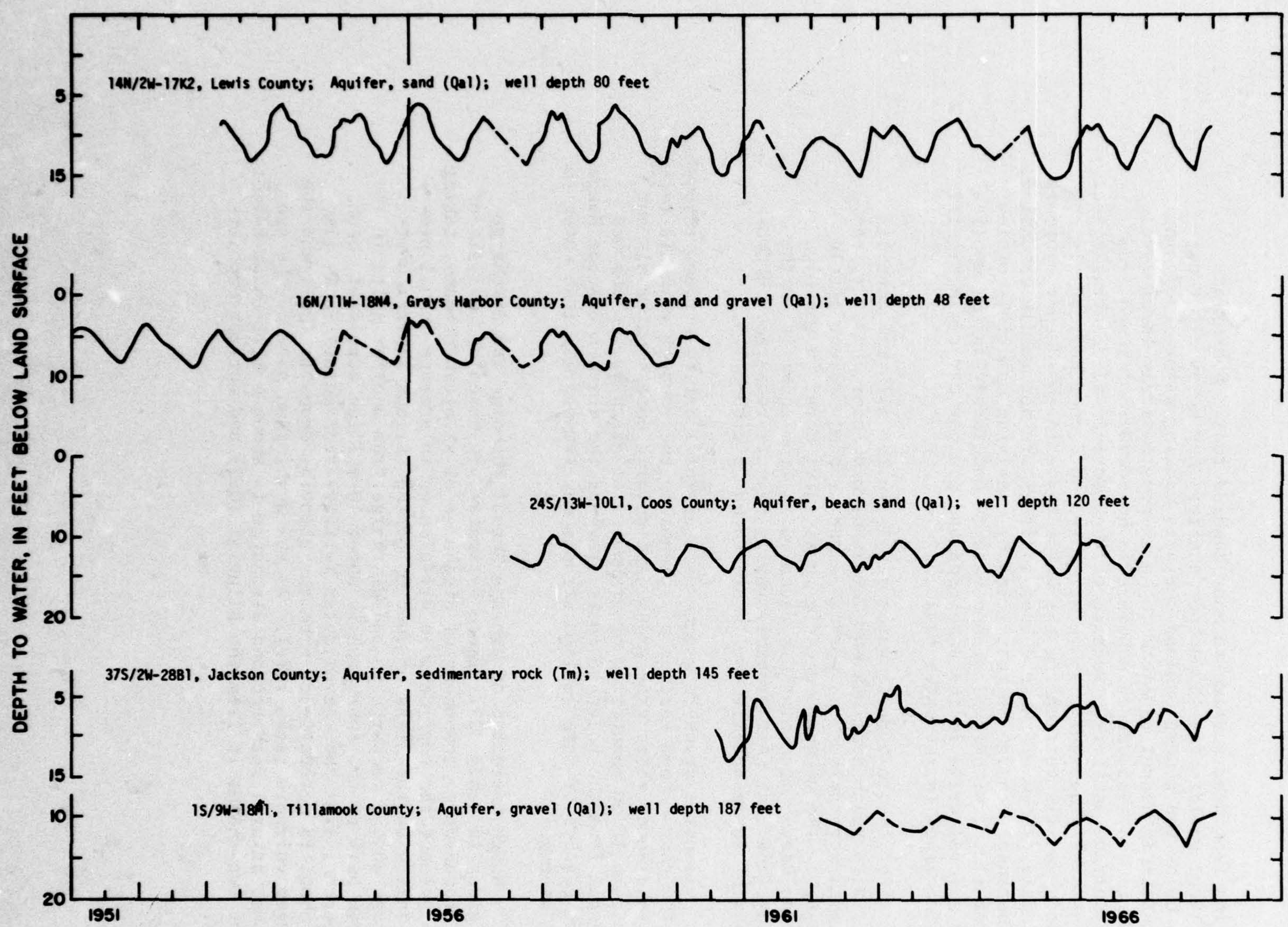


Figure 773 Hydrographs of selected wells in subregion 10

Table 426 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 10, 1970

	Ac-ft per year; all quantities in thousands		
	Oregon	Washington	Total
Irrigation			
Acres irrigated	2.0	8.0	10.0
Withdrawal	3.0	12.0	15.0
Consumptive use	2.0	6.0	8.0
Industrial 1/			
Withdrawal	20.0	1.0	21.0
Consumptive use 2/	1.0	0.0	1.0
Public Supplies			
Persons served	58.0	11.0	69.0
Withdrawal	16.0	2.0	18.0
Consumptive use 3/	3.2	.4	3.6
Rural-Domestic			
Persons served	110.0	40.0	150.0
Withdrawal 4/	12.4	4.5	17.0
Consumptive use 5/	6.2	2.2	8.5
Stock			
Withdrawal and consumptive use 6/	.25	.20	.45
TOTAL WITHDRAWAL (rounded)	50.0	20.0	70.0
TOTAL CONSUMPTIVE USE (rounded)	12.0	8.0	20.0

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

Annual Ground-Water Withdrawal

Annual ground-water withdrawal, table 426, based on 1967 data and projected to 1970, is estimated to be 70,000 acre-feet. About 50,000 acre-feet are withdrawn from aquifers in Oregon, and 20,000 acre-feet from aquifers in Washington. These withdrawals are insignificant compared with the total annual natural recharge and discharge.

Chemical Quality of Water

The chemical quality of water from the several aquifer units differs considerably. Water from the younger deposits generally has a dissolved-solids concentration of less than 250 mg/l and is soft to moderately hard. The pH of water from the alluvial deposits commonly is less than 7.0. Iron is a problem in some supplies, as is hydrogen sulfide. Water from the older rocks usually has a dissolved-solids concentration of less than 500 mg/l. Commonly, however, more highly mineralized water is encountered at depths of several hundred feet. A few wells in the Tertiary sedimentary rocks (Tm) have encountered saline water at depths of less than 100 feet. Boron, fluoride, and sodium adsorption ratio may be excessive. Sodium adsorption ratio exceeding 10 is common in water from the volcanic rocks of the western Cascade Range (Tmv), the marine sedimentary rocks (Tm), and the pre-Tertiary rocks (pT). Many wells in the Medford area have boron concentrations of 1 to 20 mg/l, and some contain excessive fluoride.

Present Use and Future Availability

Estimates of ground-water withdrawal and consumptive use in Subregion 10 are given in table 426. Annual withdrawal is about 70,000 acre-feet and consumptive use is about 20,000 acre-feet. Probably at least half of the withdrawal and consumptive use is from the alluvial deposits. Withdrawal of about 25,000 acre-feet from the alluvial deposits in Oregon is less than 2 percent of the natural recharge and discharge, and withdrawal of about 10,000 acre-feet in Washington is less than 0.5 percent of the natural recharge and discharge to those deposits. It is obvious that withdrawals could be increased manyfold without overdevelopment. However, where population and development are concentrated, local overdevelopment could occur.

In some valleys the alluvial deposits are thin, not more than a few tens of feet of material are saturated at some places. Large-diameter dug wells and infiltration trenches have been used to develop moderate to moderately large yields in a number of

places where the water table is near the land surface and the deposits are thin. Large supplies of ground water are available from beach and dune deposits in southern Oregon (11-23, 42-30). Similar supplies probably could be developed at several other places along the Oregon and Washington coasts.

The younger volcanic rocks (QTv) in the High Cascade Range are capable of yielding large to very large quantities of water to wells. Few wells obtain water from this unit because the area where that unit crops out is largely uninhabited. Increased use probably will be made of wells drilled in the younger volcanic rocks (QTv) at recreational sites. However, the great depth to water limits the utility at some places.

Wells in other aquifer units generally have only small yields; a few have moderate yields but yields of more than 50 gpm are rare. Large supplies can be obtained only by using several wells. Because of low permeability of these aquifers, the cone of depression around a well generally extends only a few hundred feet. Thus, although the capacity of an individual well is small, the aggregate capacity of the aquifers is large and they will sustain withdrawals by tens of thousands of wells. They are, and will continue to be, very important sources of water for domestic use and small public and industrial supplies. However, as was discussed in a previous section, recharge to some deep aquifers is restricted by overlying materials of low permeability. Withdrawal of moderately large quantities of water may cause significant declines in the water level in such situations.

Artificial Recharge

So far as is known, no artificial recharging is done in Subregion 10. The alluvial and beach and dune deposits could be recharged at many places; however, under present levels of development, most of the water added would be wasted by an almost immediate increase in natural discharge. In the future, if large quantities of ground water are developed from the alluvium at some places, artificial recharge with surplus surface water in the late spring may be of benefit in maintaining the water table at higher levels during the summer.

Water Rights

Oregon

In that part of Subregion 10 located in the State of Oregon, essentially the Oregon coastal basins including the Rogue and Umpqua, primary water rights for 629 wells were on file with the State Engineer's Office as of March 1967. Primary rights allow withdrawal of 72,446 acre-feet, of which 39,778 acre-feet is for industrial use and 17,170 acre-feet is for irrigation of 6,868 acres. The maximum allowed rate of withdrawal is 161 cfs (72,300 gpm), during the irrigation season. Data on supplemental-water rights are not available. Ground-water rights are summarized, by major-use category, in table 427.

Table 427 - Summary of Ground-Water Rights, Oregon Part of Subregion 10, 1967

Basin No.	Basin Name	Number of Wells	Domestic (ac-ft)	Municipal (ac-ft)	Industrial (ac-ft)	Irrigation (acres)	Irrigation (ac-ft)	Other (ac-ft)	Total (ac-ft)
1	North Coast	32	0	4,116	0	1,048	2,626	159	6,901
15	Rogue	446	0	3,589	2,840	5,066	12,658	80	19,167
16	Umpqua	44	0	14	0	526	1,315	33	1,362
17	South Coast	98	0	4,988	36,938	223	558	0	42,484
18	Mid Coast	9	0	2,419	0	5	13	100	2,532
TOTAL		629	0	15,126	39,778	6,868	17,170	372	72,446

Washington

In that part of Subregion 10 located in the State of Washington, essentially Water Resource Inventory Areas 19 through 24 (figure 666), a total of 574 active ground-water right appropriation and declaration records, in permit and certificate stages, were on file with the Department of Water Resources on September 30, 1966. Prime rights in this area allow summer period consumptive withdrawals totaling 152,697 gpm (340 cfs). A total of 780 gpm has been appropriated under supplemental rights.

Table 428 - Summary of Ground-Water Rights, Washington Part of Subregion 10, 1966

Basin No.1/	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total2/
		(Gallons per Minute)						
19	N. Olympic Pen.	-	-	585	-	-	-	585
20	N.W. Olympic Pen.	790	-	222	13	-	-	1,012
21	S.W. Olympic Pen.	-	830	863	300	-	-	1,613
23	Upper Chehalis	3,560	20,035	3,695	28,750	-	630	53,672
22	Lower Chehalis	9,500	47,962	22,011	4,462	200	5,337	60,161
24	Willapa	-	35,107	1,216	240	-	1,310	35,654
TOTAL		13,850	103,934	28,592	33,765	200	7,277	152,697

1/ Water Resource Inventory Area number as shown in figure 666.

2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.

Prime water-right quantities for the more important use categories and total actual ground-water right quantities are listed in table 428, according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

Ground water is effluent to streams everywhere in Subregion 10, except for a narrow strip along the coast where discharge is directly into the ocean. In a few broader reaches of some of the larger valleys, ground water may temporarily be prevented from entering the stream during flood stages; otherwise, ground water is effluent to streams throughout the year. Ground-water effluent makes up more than 80 percent of the average flow of streams draining the younger volcanic rocks (QTv) as indicated by records of streamflow in the Rogue and North Umpqua Rivers. No stream drains an area underlain exclusively or even mostly by the alluvial deposits (Qal) so the relation of ground water to surface water could not be determined. For all other aquifer units, the ground-water component is between 15 and 30 percent of the average annual discharge of the streams draining them. However, the ground-water component at any particular instant ranges from a few percent during floodflows to 100 percent during some periods of dry weather.

The rate of decrease in ground-water discharge during periods of no recharge is least in the younger volcanic rocks (QTv). During a 120-day recession, ground-water discharge declines to about 30 to 35 percent of the discharge at the beginning of the period, where the beginning rate is near the maximum. In contrast, the rates of decrease in ground-water discharge in other aquifer units is much greater. Usually during a 120-day recession, from near the maximum rate, ground-water discharge declines to 10 to 20 percent of the discharge at the beginning of the period. Selected hydrographs illustrating low-flow characteristics are shown in figure 774.

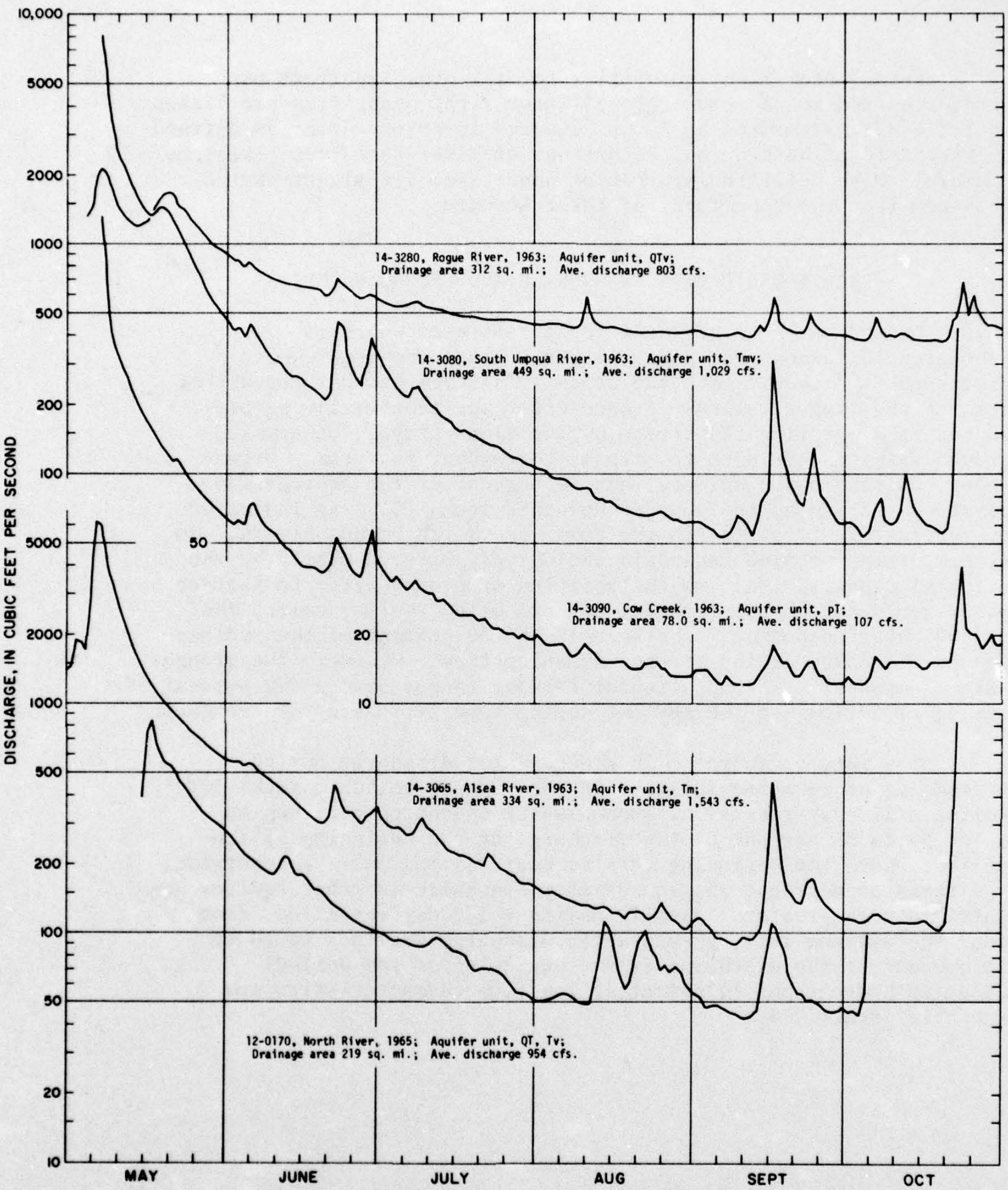


Figure 774 Hydrographs showing low-flow characteristics of selected streams

SUBREGION 11, PUGET SOUND

HYDROLOGIC FRAMEWORK

The Puget Sound Subregion lies wholly within the State of Washington and includes the area south of the international boundary that is drained by streams flowing into Puget Sound, Hood Canal, Strait of Georgia, and the Strait of Juan de Fuca east of and including the Elwha River as shown on figure 775. The area is bounded on the north by Canada, on the east by the Cascade Range, on the west by the Olympic Mountains, and on the south by a range of low hills. The area covers 13,355 square miles, of which 157 square miles are fresh water and 13,198 are land. This represents about 5 percent of the total area of the region. In addition, there are about 2,500 square miles of salt water that may be considered to lie within the subregion boundaries.

The general physiographic features of the subregion are shown on figure 2. The Puget Sound Subregion occupies a broad north-trending structural trough whose east and west flanks are composed of consolidated rocks. The mountains were eroded to their present relief and the resulting sediments were accumulated in the trough. During the glacial periods, the prominent cones of the Cascade Range were formed--Mount Baker, Mount Rainier, and Glacier Peak. Characteristic of the present postglacial terrain are numerous lakes and swales, deranged drainage patterns, and broad, deeply incised valleys. The sediments on valley floors are postglacial alluvial deposits associated with flood plains and deltas of the modern drainage system.

Streams in this subregion averaged about 54 inches of runoff per year or 53,100 cfs during the period 1929-58. Many perennial streams drain less than 1,000 square miles.

The headwaters of the streams lying on the west side of Puget Sound are in the Olympic Mountains, the site of many small alpine glaciers and perennial snowfields. A large percentage of the streamflow occurs during the winter from rainfall, with a smaller proportion in the spring from snowmelt. Stream gradients generally are about 5 percent in the upper reaches, but are less than 1 percent in the lower valleys. The principal streams are the Elwha and Skokomish Rivers, and less important are the Dungeness, Dosewallips, Duckabush, and Hamma Hamma Rivers. The Skokomish River Basin contributes about 100 inches of runoff per year, the other basins lesser amounts--down to 32 inches in the Dungeness River Basin.

Numerous rivers drain the west slope of the Cascade Mountains. Some of them originate in the many glaciers located in the north Cascades. These glaciers tend to regulate streamflow by accumulating and storing precipitation during cold, wet years and releasing more than average amounts of water during hot, dry years. This natural regulation of runoff by glaciers results in a more uniform annual distribution. Stream gradients are similar to those in the Olympic Mountains. The principal streams in the western Cascade Mountains are the Deschutes, Nisqually, Puyallup, Green, Cedar, Snohomish, Stillaguamish, Skagit, and Nooksack Rivers. The Stillaguamish River Basin discharges about 100 inches of runoff per year, the other basins lesser amounts down to about 50 inches in the Puyallup River.

Glaciers cover about 120 square miles and represent 80 percent of the glacier area in the Columbia-North Pacific Region and 60 percent of the glacier area in the conterminous United States. Approximately 36 million acre-feet of water is currently stored as glacier ice.

The native land cover is dominated by dense conifer forests. Where precipitation, soil moisture, or temperature create an environment not conducive to forest growth, grassland prairies and open park-like areas occur. On areas of well-drained soil Douglas-fir is the primary specie, but western white pine has been planted in many of these areas following logging or forest fires. The poorly drained soils are better suited for western hemlock, western red cedar, and red alder. Restocking of logged or burned areas at higher altitudes is primarily with western hemlock, Sitka spruce, and true firs. Big-leaf maple and willow occur throughout the conifer woodlands. Black cottonwood occurs in bottomland soil areas subject to flooding.

Generally, a wide variety of small trees, shrubs, and vines form a dense ground cover in all forested tracts. This cover is dominated by ferns and mosses in shaded areas. Vegetative cover of the prairie areas consists mostly of grasses. However, scattered stands of Douglas-fir and Oregon white oak are common. Scotch-broom has invaded parts of the prairie areas to the detriment of grass and woodland cover.

The cities of Seattle, Tacoma, Everett, and Bellingham are located in the Puget Sound Subregion and the concentration of population, 1,904,900 in 1965, is the highest of any area of similar size in the Pacific Northwest.

CLIMATE

Most of the air masses reaching Subregion 11 originate over the Pacific Ocean. The maritime air has a moderating influence in both winter and summer. Terrain, position, and intensity of the high- and low-pressure centers over the North Pacific, prevailing wind, and location with respect to storm tracts over the ocean, also influence the climate.

To the east and oriented in a north-south direction, the Cascade Range and Rocky Mountains shield western Washington from cold winter air masses traveling southward across Canada. Occasionally, dry continental air from the north or east reaches Puget Sound. To the west, the Coast Range on the Olympic Peninsula and Vancouver Island are effective in protecting this area from the more intense winter storms reaching the coast. The Strait of Juan de Fuca, Strait of Georgia, and the Chehalis River Valley provide low-level passages for maritime air moving inland.

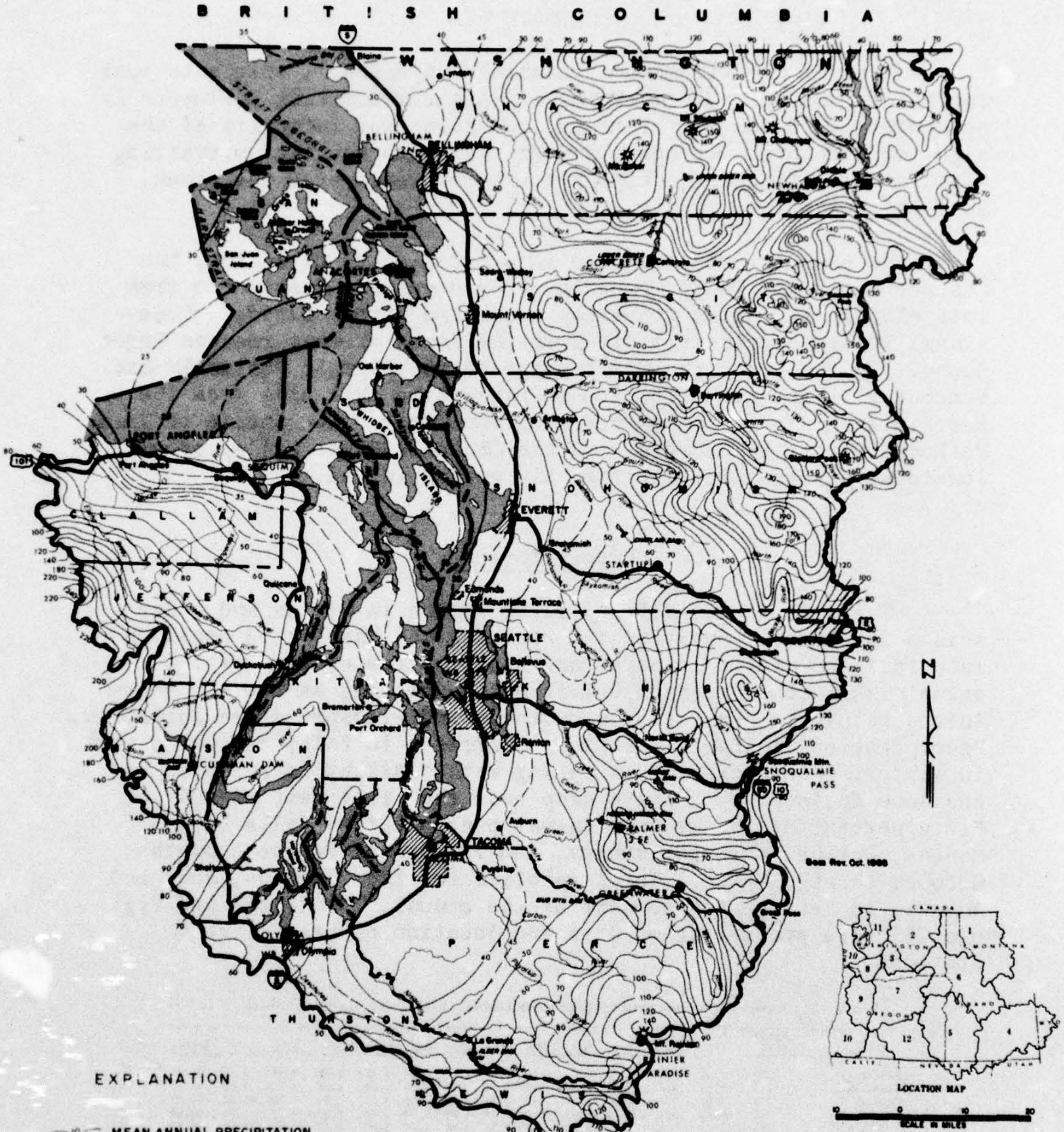
Precipitation

There is a well-defined rainy season in winter and a dry season in summer. Maritime air reaching the Washington coast in late fall and winter is moist and near the temperature of the ocean's surface. Orographic lifting and cooling as the air moves inland result in persistent cloudiness and widespread precipitation. Precipitation is light in summer, increases in fall, reaches a peak in winter, then decreases in spring with a slight increase in May and June followed by a sharp drop near the first part of July. Fifty percent of the average annual precipitation falls in the 4 months, October through January, and 75 percent in the 6 months, October through March. Total rainfall for the 2 months, July and August, is less than 5 percent of the annual. Table 429 and figure 775 give precipitation data and location of precipitation stations.

Table 429. Average Monthly and Annual Precipitation (inches), Puget Sound Subregion, 1931-60

Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Anacortes	30	3.40	2.53	2.39	1.52	1.27	1.51	0.78	0.87	1.45	2.68	3.48	3.82	25.70
Bellingham 2 N	112	4.14	3.22	3.11	2.26	1.82	1.93	.99	1.10	1.98	3.64	4.51	4.89	33.59
Concrete	270	8.80	7.03	6.76	4.12	2.87	2.75	1.30	1.50	3.57	7.03	9.10	10.38	65.21
Cushman Dam	760	16.65	12.31	10.41	6.07	3.33	2.44	1.28	1.38	3.74	9.73	14.73	18.18	100.25
Darrington	550	11.79	9.37	8.13	5.30	3.43	3.20	1.36	1.50	3.92	8.23	11.14	13.14	80.51
Greenwater 1/	1,708	7.38	6.45	5.39	4.40	3.40	3.16	1.07	1.39	3.63	6.39	8.81	9.23	60.70
Newhalem	525	10.88	8.77	7.45	4.75	2.94	2.70	1.50	1.76	4.14	8.96	11.04	13.33	78.22
Olympia WB AP	69	7.85	6.62	5.40	2.96	2.01	1.79	.76	.89	2.09	5.28	7.67	9.05	52.37
Palmer 3 SE	895	11.23	9.38	10.33	7.54	5.81	5.35	2.20	2.49	5.21	9.30	11.95	13.75	94.54
Port Angeles	99	3.87	3.06	1.99	1.08	.89	.96	.48	.58	1.10	2.48	3.77	4.35	24.61
Rainier Paradise 1/	5,550	14.90	11.22	10.65	6.43	4.68	4.42	1.68	2.81	6.00	10.79	13.64	16.51	103.73
Scenic	2,224	11.19	9.89	8.84	5.42	4.00	3.27	1.21	1.33	3.82	8.35	11.92	13.84	83.08
Seattle WB City	14	5.19	3.90	3.32	1.97	1.59	1.41	.63	.74	1.65	3.28	5.00	5.42	34.10
Sequim	187	2.18	1.73	1.30	.83	.97	1.15	.47	.59	.95	1.57	2.31	2.66	16.81
Snoqualmie Pass 1/	3,020	14.64	12.00	11.07	5.92	4.36	4.10	1.38	2.19	4.55	9.44	13.51	17.15	100.31
Startup 1 E	170	7.59	6.31	6.26	4.74	4.32	3.89	1.70	1.77	3.72	6.72	8.40	8.73	64.15
Tacoma 1/	127	5.80	4.40	3.70	2.65	1.92	1.45	.65	.76	1.94	3.49	5.68	6.45	38.89

1/ Period is shorter or longer than the 30-year normal.



EXPLANATION

MEAN ANNUAL PRECIPITATION

PRECIPITATION STATION

NOTES:

1. ISOHYETAL ANALYSIS PREPARED BY THE U.S. WEATHER BUREAU RIVER FORECAST CENTER, PORTLAND, OREGON, USING ADJUSTED CLIMATOLOGICAL DATA (1930-1957) AND VALUES DERIVED BY CORRELATION WITH PHYSIOGRAPHIC FACTORS.
2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

PUGET SOUND SUBREGION II

1968

FIGURE 775

The driest section, located northeast of the Olympic Mountains and often referred to as the "rain shadow of the Olympics," receives 17 to 30 inches of precipitation. This dry belt extends eastward from Port Angeles to near Everett and northward into the San Juan Islands. Frequently, only drizzle or light rain falls in this area, when other localities are receiving light or moderate rainfall. Annual precipitation ranges from 35 to 50 inches over most of the lowlands, and increases to 75 inches in the foothills and to 100 to 150 inches or more on the wettest slopes of the Cascade Range and Olympic Mountains.

Figure 775 is an isohyetal map of mean annual precipitation prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors.

During the wet season, rainfall usually is of light to moderate intensity and falls almost continuously rather than in heavy downpours. Measurable rainfall is recorded on 4 to 8 days each month in summer, 10 to 15 days in spring and fall, and 20 to 25 days in winter.

Most winter precipitation falls as rain at elevations below 1,500 feet, as rain or snow between 1,500 and 2,500 feet, and as snow at the higher elevations. In the mountains, snow can be expected in October and to remain on the ground from November until June or July. At elevations above 8,000 feet, snowfall in midsummer is not unusual. Winter snowfall is from 10 to 30 inches over the lowlands near Puget Sound, 75 to 100 inches in the foothills, and 300 to 500 inches in the mountains. Annual snowfalls greater than 900 inches have been recorded at the Rainier Paradise weather station.

The terrain and exposure of an area have an influence on snow accumulation. Maximum depths that can be expected are 15 to 30 inches over the lowlands, 30 to 50 inches in valleys near the mountains and over the foothills, 150 to 200 inches at 3,000 feet, and 200 to 300 inches above 4,500 feet. Density of the mountain snowpack increases from approximately 25 percent water equivalent in early winter to 45 percent in April.

Temperature

During the warmest summer months, average maximum temperatures over the islands and along the sound are in the lower 70's, increasing to the upper 70's near the foothills, then decreasing to the 60's in the mountains. Maximum temperatures reach 85° to

Table 430. Average and Extreme Temperatures (°F), Puget Sound Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bellingham 2 N	Av. Max.	43.2	47.5	51.9	58.4	64.5	69.3	73.9	73.8	69.0	60.2	51.2	45.8	59.1
48 years	Av. Min.	29.5	31.4	33.8	37.2	42.7	46.3	48.2	47.8	43.8	39.4	34.9	32.1	38.9
	Mean	36.8	39.5	43.0	48.0	53.2	57.8	61.0	60.6	56.7	50.1	43.1	39.6	49.1
	Highest	64	66	72	82	89	97	95	96	90	83	71	67	97
	Lowest	-4	-3	10	19	22	29	34	31	23	10	3	-4	-4
Concrete	Av. Max.	41.3	47.2	54.1	62.7	68.8	72.5	78.5	77.9	72.0	61.6	49.3	43.8	60.8
43 years	Av. Min.	30.0	32.4	35.0	39.4	44.7	49.5	52.1	51.9	48.7	43.6	36.7	33.5	41.5
	Mean	36.7	40.1	44.5	51.3	57.3	61.1	65.4	65.2	61.2	53.3	43.7	39.2	51.6
	Highest	69	74	82	93	96	106	102	102	102	87	74	63	106
	Lowest	-1	1	11	25	29	35	38	31	30	10	7	9	-1
Cushman Dam	Av. Max.	43.3	46.8	51.4	59.8	67.5	71.7	78.4	77.5	72.1	61.7	50.6	45.6	60.5
27 years	Av. Min.	30.9	32.3	34.1	38.3	43.7	48.0	51.0	51.3	48.7	43.5	36.8	33.9	41.0
	Mean	37.1	39.6	42.8	49.0	55.6	59.8	64.7	64.4	60.4	52.6	43.6	39.7	50.8
	Highest	65	71	76	90	93	100	104	99	96	89	75	60	104
	Lowest	-2	4	15	24	29	36	40	41	34	27	8	13	-2
Newhalem	Av. Max.	38.1	43.9	50.6	58.8	68.7	72.4	79.5	78.0	72.0	59.5	47.3	41.0	59.2
35 years	Av. Min.	29.1	31.5	34.1	38.8	44.4	48.8	52.1	52.4	49.1	43.5	36.5	32.8	41.1
	Mean	33.8	37.5	42.0	49.5	56.4	60.4	65.5	65.1	60.7	51.6	41.9	36.9	50.1
	Highest	57	71	78	91	98	109	109	105	99	83	92	65	109
	Lowest	-6	-4	9	26	31	35	41	40	32	23	7	6	-6
Olympia WB AP	Av. Max.	43.2	48.0	51.8	59.4	66.9	70.5	77.5	76.0	71.4	60.7	50.6	45.6	60.1
19 years	Av. Min.	29.9	32.4	33.1	36.7	41.9	46.6	49.3	49.0	45.4	40.6	35.5	33.3	39.5
	Mean	38.1	40.9	44.2	50.0	55.1	59.1	63.9	63.4	58.5	51.4	43.8	40.7	50.8
	Highest	63	67	75	85	92	101	103	100	95	85	74	64	103
	Lowest	0	-1	13	24	25	34	37	37	29	22	-1	12	-1
Palmer 3 SE	Av. Max.	40.9	45.2	50.2	57.8	65,0	69.2	76.1	74.9	69.4	59.6	49.1	43.5	58.4
36 years	Av. Min.	30.1	31.9	34.0	37.6	42.5	46.9	50.1	50.1	47.3	42.3	36.6	33.4	40.2
	Mean	35.5	38.5	42.1	47.7	53.8	58.0	63.1	62.5	58.3	51.0	42.8	38.4	49.3
	Highest	66	66	78	88	91	102	101	101	95	86	74	65	102
	Lowest	0	4	12	22	30	32	33	38	32	21	6	6	0
Rainier Paradise	Av. Max.	32.4	33.8	36.1	42.8	49.8	54.2	63.3	62.7	58.4	48.2	39.8	34.2	46.3
28 years	Av. Min.	19.4	20.3	21.0	26.0	31.6	36.5	42.5	43.4	39.7	32.9	26.4	21.8	30.1
	Mean	25.8	27.1	28.6	34.4	40.7	45.3	52.8	53.1	49.0	40.5	33.1	28.0	38.2
	Highest	62	62	70	70	88	86	87	92	89	79	78	62	92
	Lowest	-14	-12	-2	2	14	13	20	24	18	2	-11	-20	-20
Seattle WB City	Av. Max.	44.8	47.8	51.9	58.2	64.1	68.6	73.9	73.1	67.5	59.1	51.2	46.8	58.9
	Av. Min.	36.1	37.3	39.3	42.8	47.7	52.1	55.3	55.3	52.2	47.2	41.5	38.3	45.4
	Mean	41.2	43.6	46.4	51.8	57.4	61.4	65.6	65.0	61.2	54.4	46.9	43.8	53.2
	Highest	67	70	81	87	92	100	100	97	92	82	70	65	100
	Lowest	3	4	20	30	35	40	56	56	36	29	13	12	3
Sequim	Av. Max.	44.7	47.7	51.4	57.3	62.9	66.9	71.0	71.7	67.6	59.3	50.7	46.3	58.1
38 years	Av. Min.	30.6	32.0	33.6	37.7	42.0	47.0	49.0	49.2	46.5	41.0	35.5	32.6	39.7
	Mean	37.9	40.1	42.8	47.8	53.1	57.2	60.4	60.8	57.4	50.6	43.6	40.2	49.3
	Highest	61	66	69	80	84	91	99	94	87	76	67	63	99
	Lowest	-3	7	15	20	27	30	36	38	27	21	9	1	-3
Startup 1 E	Av. Max.	46.0	51.1	54.2	61.9	68.4	72.3	78.4	77.7	71.4	62.3	52.5	47.1	61.9
32 years	Av. Min.	33.1	35.2	36.1	39.7	44.0	47.7	49.4	49.5	46.9	42.8	37.1	34.6	41.3
	Mean	39.5	43.1	45.1	51.0	56.2	60.0	63.9	63.7	59.2	52.5	44.8	40.9	51.7
	Highest	67	72	83	90	96	106	103	100	98	87	78	65	106
	Lowest	-8	-4	6	23	28	32	35	36	32	19	4	8	-8

Note: The mean temperature is for the normal period 1931-60, other data are for the period of record through 1960.

90°F. for periods of 5 to 15 days annually, and 95° to 100°F. has been recorded in most of the lower valleys. Table 430 and figure 775 present temperature data and location of weather stations. The highest temperatures and lowest relative humidity occur during periods of easterly winds which seldom persist longer than 3 to 5 days. Average minimum summer temperatures are in the 50's over the lowlands and in the 40's in the mountains. At altitudes above 5,000 feet, below-freezing temperatures are not unusual in midsummer.

In winter, average maximum temperatures over the lowlands range from upper 30's to mid-40's and minimums from upper 20's to mid-30's. Below-freezing temperatures are observed for periods of 30 to 90 nights, depending on air drainage, distance from the sound, and elevation. Almost every winter, temperatures ranging from 10° to 20°F. occur on a few nights and zero readings have been recorded at many stations. In the mountains, temperatures can be expected to decrease 3° to 4°F. with each 1,000-foot increase in elevation. At altitudes of 3,000 to 4,000 feet, average maximum winter temperatures are near 30°F. and minimums are near 20°F. Below-freezing temperatures are recorded on most nights between October and April. The coldest weather occurs when the Pacific Northwest is under the influence of air from the interior of the continent. Outbreaks of cold air through the Fraser River canyon of neighboring British Columbia are observed each winter. Frequently, the cold air travels across the lowlands in northern counties, then westward through the Strait of Juan de Fuca; however, during the more intense surges, it may spread over the entire Puget Sound area. Outbreaks of cold air are generally of short duration.

The longest growing season, 180 to 220 days, is on the islands and near the sound. The shortest growing season, 145 to 175 days, is in valleys that are separated from the water by ridges, and in the foothills. The average date of the last freezing temperature in spring is mid-April near the water and in mid-May or later in the colder valleys. The average date of the first 32°F. temperature in the fall occurs during the last of October near the water and during the last of September in the colder areas.

Wind

The Cascade Range to the east and low-level passages through the Coast Range to the west cause a unique wind pattern. In general, the prevailing direction of the wind is south or southwest in winter and west or northwest in summer. During the winter season, the combined influences of low-pressure systems off the coast and outbreaks of cold air through the Fraser River canyon produce strong northeasterly winds over the northern counties, the San Juan

Islands, and through the Strait of Juan de Fuca. Occasionally, the northeasterly winds are felt over the entire Puget Sound. Strong southerly winds are not unusual over southern Puget Sound, while strong northeasterly winds are reported over the northern sound and through the Strait of Juan de Fuca.

In summer, winds are light. On most afternoons, a northerly or westerly breeze develops over the water and lowlands. Extreme wind velocities at 30 feet above the ground can be expected to exceed 55 mph once in 2 years, 90 mph once in 50 years, and 100 mph once in 100 years.

Evaporation

Annual evaporation from a Class A pan is estimated at 25 to 35 inches. In an average season, monthly amounts increase from 3 inches in April to 6.5 inches in July, then decrease to 3.5 inches in September. Annual evaporation losses from lakes and reservoirs are estimated at 20 to 25 inches. The annual potential evapotranspiration varies from 18 inches in the mountains to 26 inches in the warmer valleys. By assuming that soils have a 6-inch water-storage capacity and by using normal temperature and precipitation data, estimates of the actual evapotranspiration have been made. On an annual basis, this actual evapotranspiration ranges from 16 to 18 inches in the mountains and 16 to 22 inches in the lower valleys.

Storms

Thunderstorms occur locally 5 to 15 days each year. The greater number are reported over the mountains in summer, however, thunderstorms have been recorded in all localities throughout the year. Hail of sufficient size or intensity to cause damage rarely occurs.

Humidity

With the exception of brief periods of dry easterly winds, the air is moist throughout the year. In winter, the average daily range in relative humidity is from 90 percent at night to 75 percent in the afternoon; in spring and fall, from 85 to 60 percent; and in summer, from 85 to 50 percent.

Sunshine

The number of clear or only partly cloudy days each month is from 4 to 7 in winter, 10 to 15 in spring and fall, and 20 or more in summer. Approximately 20 percent of the possible sunshine is received in winter, 40 to 50 percent in spring and fall, and 60 to 70 percent in summer. The "rain shadow" area of the Olympic Mountains receives slightly more sunshine than other localities in this subregion; however, the difference is not proportional to the decrease in precipitation.

SURFACE WATER

The Elwha and Skokomish Rivers on the east slope of the Olympic Mountains have both been developed for hydroelectric power. The Dungeness River, which discharges only about one-third as much water per square mile as adjacent streams because the basin lies in the rain shadow of the Olympic Mountains, is developed for fish propagation, irrigation, and municipal supply.

The Puyallup, White, and Nisqually Rivers are used for hydroelectric power generation. Mud Mountain Dam on White River provides flood control for lower Puyallup River valley. The Green and Cedar Rivers have no glaciers at their headwaters and are used chiefly to provide large quantities of water for municipal supplies; Cedar River also produces hydroelectric power; Howard Hansom Dam located in the upper Green River Basin, provides storage for flood control and low-flow augmentation. The Snoqualmie River system furnishes both hydroelectric power and water for municipal supply. The Skagit River, the largest river in the Puget Sound Subregion, drains about 3,100 square miles, of which 400 square miles are in Canada. It is the only river in Subregion 11 that is developed to a large extent, with important hydroelectric facilities in the upper basin and on a tributary, the Baker River. Ross Reservoir, with nearly 1.5 million acre-feet of storage, has a significant influence on Skagit River in that it completely controls the flow at the dam. Navigational use is important in the lower reaches of Skagit River. The Nooksack River produces some electric power. Water is used for irrigation in most of the major river basins.

Quantity

Average discharge of streams in the subregion totals about 53,100 cfs (38.45 million acre-feet annually) of which about 1,000 cfs originates in Canada. This averages 3.9 cfs per square mile, the second highest rate of any subregion in the Columbia-North Pacific Region.

Present Utilization

Nearly three-fourths of the water withdrawn for consumptive uses (about 1,100 cfs) is for municipal supplies (350 cfs domestic and 485 cfs industrial); self-supplied industry withdraws 82 cfs. Irrigation is a minor withdrawal, only 121 cfs, but it is the major consumer, 74 cfs of the total of 235 cfs, consumed in the subregion. Thermal power is generated only in times of emergency and presently uses only insignificant amounts of water. About 2.5 percent of the average discharge was withdrawn in 1965 for consumptive uses, but less than 1 percent was actually consumed. A major amount of water is used to generate hydroelectric power. There is navigation on the lower Skagit River and large volumes of ocean-going traffic pass through the salt waters within the subregion boundaries. Recreation is popular and water use for recreation is growing rapidly. Because of the mild climate and abundance of water, recreation is becoming a major industry. All waters are used to some extent for fish and wildlife. The abundance of water makes it generally available for the transport and dilution of waste, but pollution is a problem in the lower reaches of some streams.

Stream Management

Competition for water among the various users necessitates efficient stream management. Storage and release, diversions, conservation, legal constraints, etc., all are a part of the water-management system.

Impoundments Reservoirs having a total capacity of 5,000 acre-feet or more are listed in table 431. Ross Reservoir on the Skagit River is the largest impoundment in the subregion. Although recreation was specifically considered as a use in the planning of only two of these reservoirs, most of them are heavily used for recreation.

Many of the large reservoirs are used in power production resulting in considerable regulation. River discharges change abruptly with power loads and on weekends, when less power is required, flows may be low. During the summer, municipal reservoirs are drawn down by increased water use principally to satisfy lawn-watering and air-conditioning needs. Dams, such as Mud Mountain, that were built for flood control only, remain empty except during and immediately following floods when water is released at a relatively constant rate until the reservoir becomes virtually dry.

Table 431 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More, Subregion 11

Name	Stream	Total Storage (ac-ft)	Active Storage (ac-ft)	Surface Area (acres)	Purpose 1/
Alder Lake	Nisqually R.	232,000	180,000	3,065	P
Baker Lake	Baker R.	298,000	221,000	4,985	FP
Chester Morse	Cedar R.	56,000	23,000	1,682	MP
Cushman No. 1	N.F. Skokomish R.	453,000	360,000	4,200	PR
Cushman No. 2	N.F. Skokomish R.	8,000	2,000	70	P
Diablo	Skagit R.	89,000	61,000	910	P
Gorge	Skagit R.	8,500	7,000	241	P
Howard Hanson	Green R.	106,000	106,000	2,240	FMR
Lake Aldwell	Elwha R.	30,000	3,000	580	P
Lake Chaplain	Sultan R.	14,000	13,400	444	M
Lake Mills	Elwha R.	39,000	26,000	435	P
Lake Shannon	Baker R.	159,000	142,000	2,218	P
Lake Spada	Sultan R.	20,000	-	1,527	MP
Lake Tapps	White R.	46,600	44,000	2,566	P
Lake Whatcom	Whatcom Cr.	26,400	26,400	5,003	M
Mud Mountain	White R.	106,000	106,000	1,200	F
Ross	Skagit R.	1,434,000	1,052,000	11,678	FP
Terrell Lake	Terrell Cr.	5,600	-	700	R
Tolt	S.F. Tolt R.	60,000	53,000	850	M
Youngs Lake	Cedar R.	11,000	-	700	M

1/ M-municipal, F-flood control, R-recreation, I-irrigation, P-power

Diversions With a few exceptions, the largest diversions in the Puget Sound Subregion are for municipal supplies and major industrial plants. In some areas, diversions for irrigation are important. Water is diverted in many places for hydroelectric power generation and to operate fish hatcheries and forest-product mills and plants. Where water is diverted from a stream for power generation, it generally is returned to the stream within a few hundred feet of the point of diversion; in some places, however, the distance is 10 or more miles. Return flows from diversions for other uses, such as municipal and industrial, often are discharged directly to tidewater. A large number of diversions are made throughout the Puget Sound Subregion. Diversions for various uses in the principal river basins are shown in table 432.

Table 432 - Major Diversions for Various Uses, Puget Sound Subregion

River Basin	Fish and Game (cfs)	Domestic (cfs)	Industry (cfs)	Hydropower (cfs)	Irrigation (ac-ft)
Elwha	-	4	74	2,800	-
Dungeness	25	2	-	-	75,000
Skokomish	-	2	2	2,800	-
Nisqually	-	12	10	5,650	8,000 1/
Puyallup	28	41	40	2,400	5,000
Green	-	30	55	-	4,500 2/
Cedar	-	111	74	700	-
Snohomish	-	116	185	2,520	12,000
Stillaguamish	30	-	-	-	3,000
Skagit	25	5	29	35,240	3,000
Nooksack	-	15	83	125	12,500

1/ Includes diversions in the Deschutes River Basin.
2/ Includes diversions in the Cedar River Basin.

Channel Modification Channel modification in Subregion 11 generally has been in the form of either bank protection or levee construction as flood control measures. Dredging also is sometimes used to increase channel capacity for flood control. Extensive levee systems have been built in the lower reaches of the larger rivers, especially in the Skagit, Snohomish, and Puyallup River valleys; with lesser amounts of diking along the Nooksack and Stillaguamish Rivers. Riprapping and other forms of bank protection are used in all river basins to prevent bank erosion. Clearing debris from channels, especially on the smaller streams, to aid fish migration is a continuing program in channel modification.

Forecasting Forecasting is used chiefly in flood warning and to provide a maximum of stored water for power generation and municipal use. The existing flood-warning system in the Puyallup River Basin combines Telemark instruments with radio transmission from several locations to a central point at Mud Mountain Dam. Another flood-warning system using Telemark instruments has been installed at several gaging stations in the Snoqualmie River Basin. The Weather Bureau also operates a general flood-warning system in times of major flooding.

Forecasts of quantities of water available for storage are made using snow-survey data, precipitation data, data on antecedent conditions, and other parameters. The information is processed by digital computer and updated each month as new data are obtained.

Constraints There are no interstate compacts of international treaties that are concerned with runoff in the Puget Sound Subregion, but there is a land-use agreement between the city of Seattle and the Canadian Government.

In 1966, the City of Seattle Lighting Department and the Province of British Columbia signed a 99-year land-use agreement which permits flooding the Queen's Territory to an elevation of 1,725 feet by raising Ross Lake on the Skagit River. Previous annual agreements permitted flooding to an elevation of 1,600 feet. In 1967, the water was raised to an elevation of 1,602.5 feet which is the maximum operational level for the present reservoir. Major construction will be required to raise the water level above the present maximum.

The State of Washington Fisheries Code of 1949 states that it shall be the policy of the State to maintain minimum flows in the streams to adequately support aquatic life. Several hundred minimum flows have been established under this policy; the minimums being appropriate with stream size to meet the requirement of adequately supporting aquatic life. Data on specific streams are available from the State of Washington Department of Water Resources.

Water Rights

A total of 5,844 surface-water right appropriation records in permit and certificate stages were on file with the Washington State Department of Water Resources for Subregion 11 (Water Resource Inventory Areas 1-18; figure 776) as of April 30, 1967. Prime rights in this area allow summer period diversions totaling 52,134.51 cfs of which consumptive diversions account for 3,582.40 cfs, partially consumptive diversions amount to 18,331.73 cfs, and nonconsumptive diversions account for the remainder of 30,220.39 cfs. An additional quantity of 328.20 cfs has been allocated under appropriation rights that can be classified as supplemental.

A total of 20 adjudicated surface-water right records in this subregion permit additional prime-right consumptive diversions totaling 579.56 cfs. These rights are all associated with the Dungeness River Decree.

Recorded reservoir-storage rights (permits and certificates) under the appropriative system allow a total quantity of 5,377,240 acre-feet to be retained in storage annually within the Puget Sound Subregion.

Prime water-right quantities for major-use categories and total actual surface-water right quantities are listed in table 433 according to Water Resource Inventory areas as defined by the State of Wasnington, Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

Discharge

A typical Subregion 11 stream, South Fork Skykomish River near Index, Washington, shows a base-period mean discharge equal to 99 percent of its long-term mean (57 years, 1903-05, 1912-65). Weather records show that precipitation in Seattle during the base period was 98 percent of the long-term mean (88 years, 1878-1965). Thus, the selected base period provides reasonably average data for statistical analysis.

Measurement Facilities Table 434 summarizes pertinent streamflow data for the 17 sites selected for detailed study in Subregion 11.

Figure 776 Map showing water resource inventory areas defined by the State of Washington Department of Water Resources.

Table 433 - Surface Water Rights in the Puget Sound Subregion, 1967

Basin No.1/	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total2/	Reservoir Storage Rights
				(Cubic Feet per Second)					(Acre-Feet)
Appropriative Rights									
01	Nooksack	308.12	119.45	46.27	39.81	19.57	3.24	644.17 3/	5,671
02	San Juan	-	4.94	1.93	-	0.74	1.85	9.35	1,017
03,04	Skagit	161.50	48.53	56.67	29.54	106.63	0.81	37,974.22 4/	4,414,089 5/
05	Stillaguamish	10.60	35.48	16.41	11.88	52.45	0.59	114.41	56
06	Whidbey	-	6.80	2.71	-	0.86	0.34	10.58	147
07	Snohomish	695.13 6/	83.78	57.69	108.38	244.77	1.10	1,805.18 7/	195,935 8/
08	Cedar-Sammamish	25.87 9/	84.91	66.87	170.98 10/	61.86	0.91	568.28 11/	2,801
09	Green-Duwamish	118.28 12/	58.85	11.24	11.15	39.00	1.25	244.47 13/	42
10,12	Puyallup	725.45	55.59	84.22	40.00 14/	70.33	9.28	961.73 15/	51,671 16/
11	Nisqually	25.00	32.13	14.31	236.32	13.16	1.76	5,922.85 17/	210,060 18/
13	Deschutes	10.00	35.86	4.53	12.13	11.32	0.37	78.38	414
14	Shelton Area	5.00	38.57	19.79	58.32	11.30	0.65	125.61 19/	2,317 20/
15	Kitsap Area	32.75 21/	42.19	33.55	2.66	65.61	1.21	181.78 22/	7,767 23/
16	E. Olympic Mts.	0.50	12.35	41.42	0.70	73.47	0.15	2,709.37 24/	417,300 25/
17	N.E. Olympic Pen.	30.00	12.90	17.70	30.08	43.59	0.97	93.55	2,813
18	Port Angeles Area	31.40	52.46	14.70	190.02	32.94	1.53	915.59 26/	65,140 27/
Appropriative Totals		2,179.60	724.79	490.01	941.97	847.60	26.01	52,359.51	5,377,240
18	Port Angeles Area	-	579.56	579.16 24/	-	-	579.16	579.56	-
Adjudicated Totals		-	579.56	579.16	-	-	579.16	579.56	-
Combined Totals (Approp. & Adjud.)		2,179.60	1,304.35	1,069.17	941.97	847.60	605.17	52,939.07 29/	5,377,240

1/ Water Resource Inventory Area number as shown in figure 776.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable category.
3/ Includes 21.23 cfs under recorded rights for hydroelectric power generation plus an additional 125 cfs under a claim to a vested right.
4/ Includes 37,607.26 cfs under recorded rights for hydroelectric power generation.
5/ Approximately 80 percent of the developed water-storage capacity in the Puget Sound Subregion is in the Skagit River Basin. This figure includes 3,800,000 acre-feet for Ross Lake (1,405,300 acre-feet developed), 90,000 acre-feet in Diablo Reservoir, 8,350 acre-feet in Gorge Reservoir, 298,000 acre-feet in Baker Lake, 190,000 acre-feet in Lake Shannon, and 3,050 acre-feet in Judy Reservoir.
6/ Includes rights of 400 cfs, mainly from the Sultan River, for the city of Everett, and 280 cfs, from the Tolt River, for the city of Seattle.
7/ Includes 651.79 cfs under recorded rights for hydroelectric power generation.
8/ Includes 13,200 acre-feet in Lake Chaplain, 113,700 acre-feet (20,000 acre-feet developed) for Spada Lake, 57,830 acre-feet in the S. Fork Tolt River Reservoir, and 1,100 acre-feet in the Tolt River regulating reservoir.
9/ The city of Seattle has a claim to vested rights for an additional 317 cfs.
10/ Includes 156 cfs for heat-exchange use.
11/ Includes 208.88 cfs under recorded rights for hydroelectric power generation. Does not include 500 cfs for a claimed vested right by the city of Seattle.
12/ Included is a 1908 priority right for 100 cfs held by the city of Tacoma.
13/ Includes 8.93 cfs under recorded rights for hydroelectric power generation.
14/ Includes 11.50 cfs for mining.
15/ Includes 20.13 cfs for recreation and beautification, and 14.49 cfs for hydroelectric power generation.
16/ Includes 50,400 acre-feet in Lake Tapps.
17/ Includes 5,633.70 cfs under recorded rights for hydroelectric power generation.
18/ Includes 200,000 acre-feet for Alder Lake and 10,000 acre-feet for LaGrande Reservoir.
19/ Includes 23.23 cfs under recorded rights for hydroelectric power generation.
20/ Recreational reservoirs account for most of the water under storage rights.
21/ Includes rights of the city of Bremerton to divert 30 cfs from the Union River drainage system. Bremerton also has a right to divert 10 cfs from the West Fork Union River, but only during the winter months.
22/ Includes 32.53 cfs under recorded rights for hydroelectric power generation.
23/ Includes 1,200 acre-feet in Twin Lakes and 4,000 acre-feet in the Union River Reservoir.
24/ Includes 2,623.47 cfs for hydroelectric power generation - mostly associated with the city of Tacoma developments on North Fork Skokomish River.
25/ All rights are associated with hydroelectric power developments of the city of Tacoma.
26/ Includes 602.20 cfs for hydroelectric power generation.
27/ Nearly all of this quantity is associated with hydroelectric power plants on the Elwah River.
28/ Quantity is common with irrigation use.
29/ Includes 225 cfs under claims to vested rights.

Figure 432 shows the locations of the selected sites, with Geological Survey identification numbers. The first two digits of the identification number, part number (12), have been omitted because Subregion 11 lies wholly within the area designated as Part 12, the Washington coast and the Columbia River Basin above Snake River.

Table 434 - Streamflow Summary for Selected Sites, Subregion 11

Stream	Station	Station Number	Gage Datum	Drainage Area (sq. mi)	Period of Record	Annual Flows1/ Mean (cfs)	Annual Flows1/ Max. (cfs)	Annual Flows1/ Min. (cfs)	Momentary Flow2/ Max. (cfs)	Momentary Flow2/ Min. (cfs)
Elwha River	Port Angeles	455	200	269	18-65 3/	1,456	2,051	859	41,600	10
Dungeness River	Sequim	480	569.3	156	37-65 3/	371	545	199	8,400	77
Duckabush River	Brinnon	540	241.49	66.5	38-65 3/	392	537	217	8,960	45
N.F. Skokomish River	Hoodsport	565	762.26	57.2	24-65	487	688	256	27,000	16
Nisqually River	La Grande	865	490	292	43-65 3/	1,385	2,092	803	20,700	0
White River	Greenwater	970	1,725	216	29-65	837	1,222	558	18,100	120
Puyallup River	Puyallup	1015	0	948	14-65	3,292	4,927	2,087	57,000	400
Green River	Auburn	1130	0	399	36-65	1,306	1,875	662	28,100	81
S.F. Skokomish R.	Index	1330	574.80	355	11-65 3/	2,385	3,383	1,352	55,000	165
Snoqualmie River	Carnation	1490	0	603	28-65	3,714	5,190	2,314	59,500	239
S.F. Stillaguamish R.	Granite Falls	1610	310	119	28-65	1,045	1,466	702	32,400	55
N.F. Stillaguamish R.	Arlington	1670	89.34	262	28-65	1,770	2,439	1,120	30,600	117
Skagit River	Hope	1706	1,670	357	35-55	977	1,600	488	-	-
Skagit River	Newhalem	1780	401.5	1175	-8-65	4,351	6,276	2,717	115,000	54
Sauk River	Sauk	1895	266	714	28-65	4,241	5,923	2,887	82,400	572
Skagit River	Concrete	1940	130.0	2737	24-65	14,224	20,003	9,507	500,000	2,160
Nooksack River	Deming	2105	203.6	584	35-57 3/	3,217	4,342	2,220	49,300	502

1/ Regulated values for base period (1929-58) with estimated 1970 conditions of development.
2/ Maximum and minimum observed instantaneous values for period of record.
3/ Denotes other short periods of record prior to dates shown.

Average Discharge for Subregion 11 Figure 777 presents monthly discharge data for the subregion as a whole. The discharge is the sum of flows generated within the subregion and the inflow to the subregion from Canada. The Canadian contribution is not large, but its high flow occurs during the spring when other flows are low and the inflow may be as much as 6 percent of the total monthly flow at that time. The within-area generated flows and the Canadian inflow are shown in table 435 Isopleths showing mean annual runoff for the period 1931-60 are shown on figure 778.

Average Discharge for Selected Stations In this section of the report detailed data for each of the selected sites listed in table 434 are presented.

The monthly discharges upon which these hydrographs are based are generally available in Geological Survey Water-Supply Papers 1316 and 1736 compilations of surface-water records in Part 12. The three principal exceptions are Nisqually River at La Grande, Skagit River at Newhalem, and Skagit River near Concrete where assumed reservoir regulation has provided adjusted flows through a computer program. Monthly discharges for these sites are listed in tables 436, 437, and 438. Records for Skagit River at Hope, B. C., have been extended for the base period by correlation with downstream gaging stations and these discharges are shown in table 439. Observed discharges for the remaining 13 selected sites

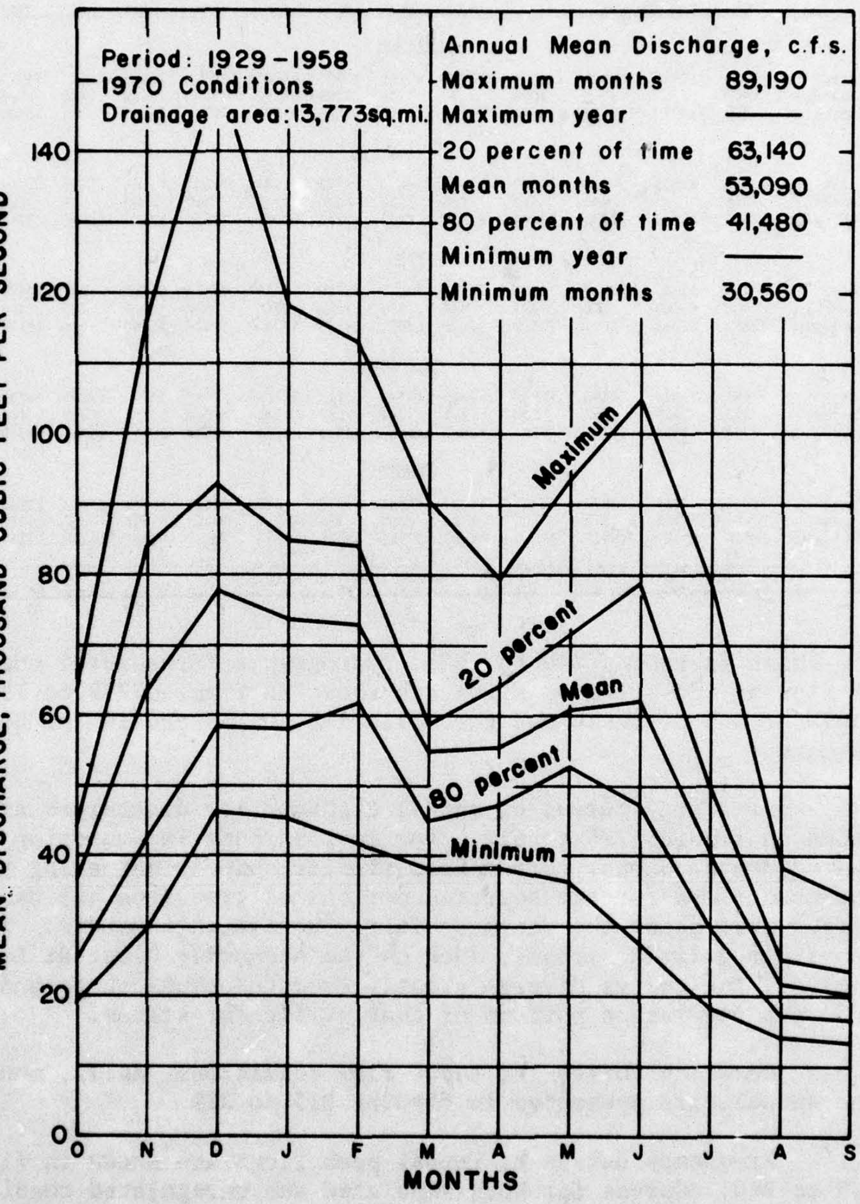


Figure 777 Monthly discharge, Puget Sound Subregion, 1929-58. (Inflow from Canada is included.)

Table 435. Discharge in Puget Sound Subregion, 1929-58
(Mean discharge, in cfs)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Mean
Maximum													
Total	62720	115280	150468	117696	112285	89156	78925	93063	104391	78115	38177	34373	89188
Canada	1000	1360	1650	1090	1530	1250	3300	4180	6560	3970	1480	892	2355
Subregion	61720	113920	148818	116606	110755	87906	75625	88883	97831	74145	36697	33481	86833
20 Percent													
Total	43127	83515	92363	84447	83525	58638	63772	71143	78609	49664	25213	23702	63143
Canada	576	960	930	553	706	586	1520	3240	4010	2030	678	351	1345
Subregion	42551	82555	91433	83894	82819	58052	62252	67903	74599	47634	24535	23351	61798
Mean													
Total	36238	62710	77243	73302	72543	54511	55299	60526	61914	39809	21868	20479	53090
Canada	406	562	566	423	464	454	1154	2780	2806	1316	493	304	977
Subregion	35832	62148	76677	72879	72079	54057	54145	57746	59108	38493	21375	20175	52113
80 Percent													
Total	24181	41613	57893	57349	61303	44900	47212	52524	47287	29538	17195	16739	41478
Canada	207	214	297	236	211	244	682	2130	1940	706	305	201	614
Subregion	23974	41399	57596	57133	61092	44656	46530	50394	45347	28832	16890	16538	40864
Minimum													
Total	18616	28782	46077	45437	41721	37933	38418	36035	27650	18339	14332	13532	30558
Canada	136	115	122	125	94	180	385	1080	853	388	202	165	320
Subregion	18480	28667	45955	45312	41627	37753	38033	34955	26797	17951	14130	13367	30238

Note: 1. Subregion discharge is that which originates in the subregion.
2. Twenty percent and 80 percent represent the discharge available 20 and 80 percent of the time.

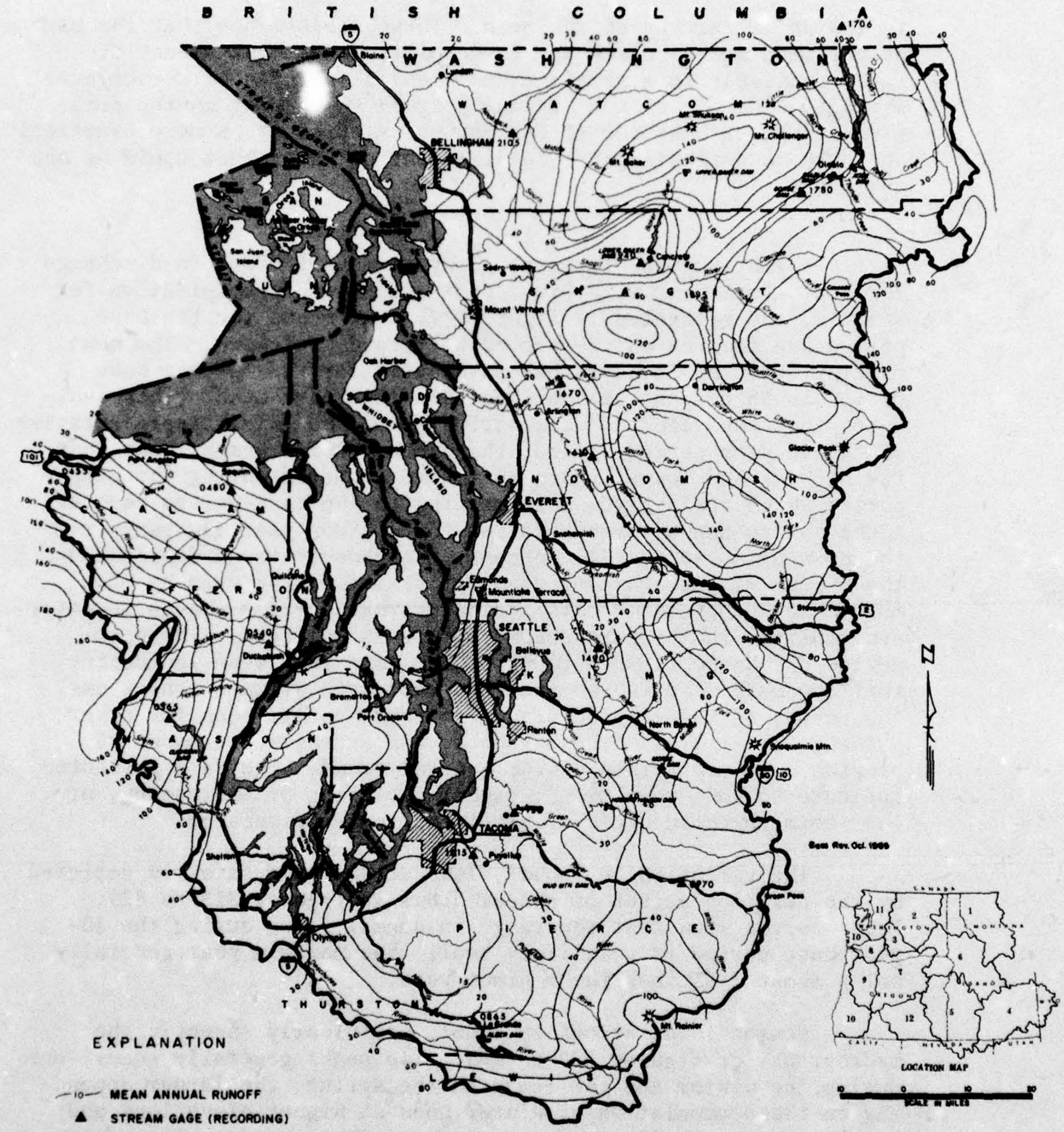
are shown in tables 440 to 452. Hydrographs for several conditions of flow at the selected sites are shown on figures 779 to 795. Explanations of these and the following graphs are in the Regional Summary

Frequency curves of annual high and low discharges are shown on figures 796 to 812. For most streams in Subregion 11, the volume frequency curves have similar shapes indicating that the mean flows for the selected periods of time (months) usually differ throughout the years by fairly consistent amounts. In heavily regulated streams, such as the Nisqually River at La Grande, however, the curves diverge greatly from the usual shape and reflect only the regulation pattern of that particular stream.

Duration curves for three flow conditions, daily, monthly, and annual, are presented in figures 813 to 829.

Frequency curves of annual peak flows are shown in figures 830 to 846. Curves for both regulated and unregulated conditions are presented where data permit.

Dependable yield of the river basins is given in tables 453 to 469. The tables show the lowest mean flows for from one to ten consecutive years in the 30-year base period and their relationship to the 30-year mean. The minimum-year discharge is less than 70 percent of the mean, averages 60 percent of the mean, and ranges



EXPLANATION

—10— MEAN ANNUAL RUNOFF

▲ STREAM GAGE (RECORDING)

NOTES:

1. MEAN ANNUAL RUNOFF ISOPLETHS HAVE BEEN DRAWN BY U.S. GEOLOGICAL SURVEY, USING OBSERVED STREAMFLOW DATA ADJUSTED TO NATURAL CONDITIONS (1931-1960) AND CORRELATED WITH CLIMATOLOGICAL AND PHYSIOGRAPHIC FACTORS.

2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC

COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

PUGET SOUND SUBREGION II

1968

FIGURE 778

as low as 50 percent of the mean. These tables show that the use of the mean annual discharge to determine the total amount of water available in a stream is not realistic, even with carryover storage. The use of the minimum year or some point on the duration curve, such as the 90 percent point, presents a more practical approach to estimating the total amount of water that could be made available.

Variations in Discharge Long-term variations in discharge for South Fork Skykomish River near Index, and precipitation for Seattle, are presented in figure 847. The means for the base period and for the entire period of record are shown. The mean precipitation of 33.02 inches at Seattle for the 30-year base period is 98 percent of the long-term (88-year) mean. This indicates that the selected base period should be fairly representative of the 88-year period. Also, the precipitation graph shows that the highest and lowest years of record occurred during the base period which again gives more meaning to the base-period record. Although the annual precipitation for a given year may vary from the mean by as much as 43 percent, the general trend depicted by the 5-year moving averages does not vary from the mean by much more than 20 percent. This indicates that a large change in water availability in the foreseeable future is unlikely. The base-period discharge is 99 percent of the long-term mean indicating that the data used in the analyses represent average conditions. The ratios of base-period discharge to long-term mean for other streams are similar. The 5-year moving averages are shown to provide easy comparison of the general trend. The data presented indicate no long-term trend, either declining or increasing, or long-term rhythmic cycle of precipitation or discharge.

The variation in annual flows at selected sites is depicted by the duration curves of annual flows in figures 813 to 829. These curves show that the range in annual flows during the 30-year base period is relatively small, the maximum year generally being about 2.5 times the minimum year.

Seasonal variations in runoff are clearly shown in the hydrographs of figures 779 to 795. Two peaks generally occur, one during the winter and the other in the spring, the larger depending on the accumulation of winter snow at higher elevations and precipitation patterns; glaciers, temperature, and geology also have an effect. December usually has the greatest rainfall runoff and June the largest snowmelt runoff. The low runoff months are August, September, and October. Streams that receive large amounts of flow from surface or underground reservoirs have the smallest variations in monthly flows.

Streamflow Travel Time Only limited time-of-travel studies have been made in Subregion 11. Figures 848 and 849 show time of travel of maximum concentrations of Rhodamine B dye for designated discharges in the lower reaches of four streams. The shortest time of travel, 19 minutes per mile, was determined in Green River near Palmer; Green River averaged 23 minutes per mile between Palmer and Tukwila. The longest time of travel, 89 minutes per mile was measured in Stillaguamish River near Florence; Stillaguamish River averaged 79 minutes per mile between Arlington and Florence.

River Profiles River profiles for selected streams are shown in figures 850 to 852. The profiles were constructed from Geological Survey plan and profile sheets. Very few river profiles have ever been developed for streams in this subregion.

(Narrative continued on page 927)

Table 436 -- Modified Mean Discharge, in CFS, Nisqually River at La Grande, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										860	550	1220	
1929	785	920	1163	1937	1069	1290	756	754	787	870	578	696	967
1930	751	753	751	2005	1100	1601	750	751	507	509	540	836	904
1931	753	770	1944	1929	1829	940	1130	752	500	793	2005	500	1154
1932	1937	1843	1730	1811	1930	2096	1678	274	1670	1101	639	1230	1495
1933	625	2803	2591	2561	2356	0	1180	1900	2700	1460	870	1580	1719
1934	1572	1385	7267	4030	1180	1860	1310	1060	660	620	560	1180	1890
1935	1615	2571	2580	2547	2474	1465	598	516	1260	840	550	1250	1522
1936	365	760	937	2421	2342	2062	987	701	2000	900	590	1240	1275
1937	405	616	1475	1567	1533	1409	1747	1047	2113	747	628	1221	1209
1938	692	2543	2602	2605	2401	0	1600	1570	1080	750	490	1170	1459
1939	445	1152	1765	2380	2297	1774	392	34	1110	850	570	1200	1164
1940	485	833	2434	2351	2270	2235	307	577	764	251	438	1180	1177
1941	535	1207	1272	2317	1717	177	16	208	96	258	1098	732	803
1942	1116	1786	2412	2317	1849	389	0	0	1034	980	600	1170	1138
1943	365	2469	2429	1921	2277	0	2114	1290	1350	970	520	1220	1410
1944	515	842	1563	2312	1893	507	406	0	309	288	1485	598	893
1945	1168	1054	1334	2007	2150	1379	1200	0	799	407	582	1164	974
1946	1242	2055	2331	2333	2268	0	1201	2150	1820	1220	630	1170	1535
1947	855	2160	2595	2581	2431	122	1460	1120	930	690	450	1210	1384
1948	1274	2531	2109	2452	2403	99	1530	2490	1900	1040	700	1330	1655
1949	755	1860	1843	1703	2183	151	1381	2900	1590	1110	720	1340	1461
1950	825	2221	2023	2378	2386	1774	1950	2030	2400	1420	850	1330	1799
1951	1236	2548	2762	2578	3271	1210	1780	1650	1100	740	510	1220	1635
1952	1119	1884	1759	1580	2314	0	1142	1700	1060	900	580	1230	1272
1953	405	565	724	3462	2586	672	1506	1334	1390	1170	700	1330	1320
1954	755	1650	2571	2596	2872	1420	2010	1940	1860	1390	850	1091	1750
1955	1064	1858	1792	1871	2252	125	2024	416	2650	1630	930	1470	1507
1956	2125	3133	3990	2563	1610	1052	2500	2760	2040	1340	760	1230	2092
1957	1045	1530	2470	1841	2274	497	1850	1730	1190	760	560	1330	1424
1958	585	1152	2245	2411	2438	206	1970	1490	1230	860	550	1220	1363
Mean	914	1648	2182	2312	2132	884	1283	1171	1330	895	718	1156	1385

Table 437 Modified Mean Discharge, in CFS, Skagit River at Newhalem, Wash

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										5340	2590	2102	
1929	4217	4657	3919	4581	4423	1155	1002	2815	1817	4147	2665	1787	3098
1930	2453	3679	3458	4486	7043	2432	5618	1440	2405	3017	2793	2392	3434
1931	2883	4373	3573	6155	6284	2804	1996	4581	2252	2112	2262	2746	3501
1932	2589	5617	4295	5510	10698	4501	1925	1569	6910	5561	3313	2054	4545
1933	3478	9561	6392	2063	5786	1000	1034	1135	13473	11446	5340	3430	5344
1934	7169	7217	4932	5052	3812	5997	10344	11520	8366	5220	3365	2318	6276
1935	3311	9005	5906	6479	9342	1000	1000	1412	8814	6828	3344	3158	4966
1936	2807	4013	3820	4453	5006	1505	5103	2306	6221	4025	2684	2105	3670
1937	2500	3727	4176	4530	4398	1682	1197	1505	10445	4424	2662	2210	3621
1938	3793	6777	6020	5808	5686	1000	1264	1604	11761	5772	2395	2348	4519
1939	2825	4408	4808	6747	5289	2068	1214	1664	5900	6150	3043	1976	3841
1940	3231	5380	7641	5330	6515	1000	1000	1594	5590	1268	1996	2166	3559
1941	5202	4782	5113	5691	5611	2053	2512	1049	1289	1443	1114	1038	3074
1942	4761	6602	7189	5294	5002	1091	1000	1230	1604	3941	2617	1730	3505
1943	2290	4679	5106	3540	3808	1000	1377	4019	11730	10106	3765	2351	4480
1944	2843	4209	4413	5108	4821	1263	1556	1218	1516	1252	1623	2786	2717
1945	3180	4801	4725	6426	7335	2574	2594	1741	2350	2916	2421	2302	3613
1946	4274	6079	4532	5633	5239	1000	1156	4666	11010	7269	3430	2220	4709
1947	2915	4294	3358	2790	4834	1000	1414	10651	8827	5068	2556	2104	4150
1948	4462	4408	4868	2501	3633	1000	1133	6797	17400	5586	4001	3015	4900
1949	4151	4998	4186	4890	5107	1000	1376	6140	10380	6191	3402	3037	4571
1950	3703	10180	7102	2244	4063	1000	1000	3569	19380	11146	4768	2699	5904
1951	4863	7304	7249	3338	3867	1985	3807	11500	11370	7064	3228	2630	5683
1952	3248	4852	3670	2436	4362	1000	1287	3767	8103	5502	3032	2058	3609
1953	2395	3903	3532	6354	6076	1000	1175	1947	9213	8317	3921	2910	4228
1954	4623	6949	6263	2141	5421	1000	1000	6651	13100	13756	6419	3956	5939
1955	4077	9012	6295	3510	6018	1000	2819	1458	7344	9787	4194	2698	4851
1956	6380	8717	2829	1471	3115	1000	1394	13347	14080	9598	4093	3378	5783
1957	5939	6388	6951	3326	5414	1000	1099	6527	9332	4334	2645	2378	4611
1958	2843	4552	4331	3137	4855	1000	1000	5691	8554	5340	2590	2102	3832
Mean	3780	5837	5022	4367	5429	1604	2047	4170	8351	5953	3189	2470	4351

Table 438 - Modified Mean Discharge, in CFS, Skagit River Near Concrete, Wash.
(Includes inflow from Canada)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										15550	7452	6259	
1929	13076	11600	9106	9957	9339	6574	7291	16415	16037	12399	7701	5096	10382
1930	6242	7816	9213	9921	20369	9483	16938	11190	12665	10719	7460	6457	10706
1931	9047	10936	8725	18021	15770	11861	11707	18941	16092	9584	6542	8752	12164
1932	8840	16268	12363	14649	25302	16465	13635	14679	26408	18991	10187	6539	15360
1933	11540	29830	18032	11517	13401	6557	8294	16706	36723	31926	16160	12406	17757
1934	21500	20375	26037	21960	14247	19043	26282	20371	23044	15684	9610	7661	18817
1935	11663	25335	16301	23647	22058	7182	7409	[illegible]143	26538	19201	9170	9036	15890
1936	7861	10003	9609	13469	11540	8484	17220	18793	27027	13730	7640	6347	12658
1937	6691	8272	12790	9978	10342	8593	9811	14385	32927	15336	7884	6257	11938
1938	11285	21203	17624	16433	13231	5736	10107	16939	29499	15877	6757	6435	14260
1939	8834	12709	15078	20113	13239	8979	10858	15737	22502	20068	9260	6343	13643
1940	10202	15093	22150	14942	16933	9730	8924	14526	17034	6669	6301	6109	12384
1941	14218	12367	13850	13943	13201	7836	9408	10385	8568	6668	5277	8174	10324
1942	15643	16797	19075	12014	12052	6036	7157	11126	16103	14237	7391	4985	11884
1943	6564	14950	15031	11694	12661	6622	13034	18023	29345	25948	10197	6708	14239
1944	7768	10172	11739	13042	11871	6601	8211	11931	11645	6723	5669	8714	9507
1945	9734	13863	11833	18205	18908	9182	9422	14438	17442	11551	7197	7527	12446
1946	11658	17470	12819	15614	14243	6674	8709	25147	30161	21403	10019	6538	15037
1947	10067	12247	14429	11601	16084	6941	11890	29064	25301	15884	7818	6775	14008
1948	15849	14351	15826	10960	11492	5620	8584	26524	43703	17825	12024	9825	16048
1949	12114	14533	10859	11172	13313	7330	9743	29317	28764	19748	10547	9292	14727
1950	12849	28378	19601	11338	14899	9547	11201	21039	45353	41881	15235	8721	20003
1951	16226	21056	23647	13375	21001	8559	14816	29654	28946	18026	8575	7609	17624
1952	12573	13058	10323	7902	13478	4565	8922	20387	23453	17054	8688	6062	12205
1953	6527	9141	9041	23419	18983	5430	7565	16232	23975	23497	11450	8660	13660
1954	14092	19594	19823	11725	18765	6720	8355	24879	32904	34216	17985	12240	18433
1955	12326	25312	15763	10952	15209	4618	12485	12543	29081	28011	13102	7981	15615
1956	19121	25433	13397	9755	9241	5679	12765	34789	36272	24872	11378	10108	17734
1957	17682	16578	20529	9831	15162	7029	8765	27317	24347	15056	8088	6994	14781
1958	8053	11433	12021	13536	15334	5274	6876	24016	24073	15550	7450	6390	12503
Mean	11662	16206	14888	13823	15056	7965	10879	19288	25531	18278	9425	7687	14224

Table 439 Observed Mean Discharge, in CFS, Skagit River Near Hope, B.C.
[Discharges estimated from July 1928 to September 1934 and October 1955 to September 1958]

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										930	318	211	
1929	521	295	218	152	102	216	434	2310	2280	646	305	179	638
1930	168	129	297	126	706	531	2050	1890	1950	828	364	222	768
1931	210	254	181	373	590	586	853	2780	1720	541	236	278	717
1932	202	447	334	336	1040	930	1370	2810	3060	967	483	214	1016
1933	311	1100	782	396	269	322	1080	2290	4270	2680	1050	351	1242
1934	894	954	1050	1070	941	1250	3300	3240	1940	816	466	235	1346
1935	282	1010	618	1090	1530	519	560	2130	2710	1330	495	308	1048
1936	217	184	213	184	120	232	1720	3310	1910	538	263	192	757
1937	145	115	277	125	94	287	682	2440	4120	1230	395	240	847
1938	329	651	667	542	282	520	1140	3210	2870	903	311	199	971
1939	181	196	387	553	211	457	1520	2820	2140	1190	405	201	859
1940	243	419	1020	465	417	614	1060	1860	1070	431	224	165	667
1941	362	243	365	310	343	431	944	1080	853	388	202	334	488
1942	1000	848	1040	361	245	225	893	1670	1740	781	337	172	779
1943	136	237	528	471	413	490	2010	2160	3160	2090	570	264	1040
1944	207	193	285	175	152	180	576	1510	1530	549	285	260	492
1945	253	281	385	470	474	284	385	2320	2120	818	305	238	695
1946	469	672	380	329	256	430	986	3890	2850	1280	465	245	1030
1947	241	214	471	312	586	823	1500	3280	2180	882	362	237	925
1948	533	583	552	463	276	244	870	3380	5090	1110	651	439	1180
1949	528	373	302	236	191	386	1440	3880	2750	1270	706	522	1050
1950	432	1200	1070	430	429	592	777	2680	6560	3500	678	317	1560
1951	602	1180	1650	788	1010	477	1520	3270	3070	1450	477	277	1320
1952	377	404	343	221	268	219	1390	2970	2160	1060	360	201	832
1953	147	139	122	561	824	396	910	2930	3080	2030	700	416	1020
1954	679	960	785	549	766	593	885	3570	4010	3970	1480	892	1600
1955	576	1360	930	496	351	289	665	1710	4430	2530	847	420	1220
1956	903	1310	489	309	190	229	1550	4180	4160	2260	679	502	1397
1957	811	640	933	327	321	465	915	4180	2330	706	326	265	1018
1958	210	272	304	467	509	416	642	3640	2060	720	369	335	829
Mean	406	562	566	423	464	454	1154	2780	2806	1316	493	304	977

Table 440 --Observed Mean Discharge, in CFS, Elwha River at McDonald Bridge Near Port Angeles, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1050	620	434	
1929	830	1080	1000	813	476	511	900	1790	2140	1390	753	424	1010
1930	485	328	642	609	2200	1190	2040	1240	1490	996	550	423	1010
1931	638	717	780	1920	1560	1550	1460	1930	1950	1160	508	532	1220
1932	608	1580	1470	1350	[illegible]	1980	1760	2040	2840	1710	828	495	1540
1933	706	2470	1930	1700	[illegible]	1100	1050	1720	3000	2820	1530	1050	1660
1934	1424	1738	4713	3445	1923	2234	2065	1898	1362	917	635	503	1910
1935	1005	3105	1487	3513	2792	1671	1028	1610	2249	1575	863	829	1803
1936	604	565	921	1592	635	1270	1435	2682	2469	1279	687	617	1232
1937	400	219	1141	638	538	1044	1306	2077	3155	1757	773	536	1135
1938	802	2481	2902	1800	871	1245	1546	2219	2533	1393	729	435	1584
1939	625	945	1639	2391	1102	944	1396	1880	1460	1262	695	473	1237
1940	510	1029	3619	2262	2029	2094	1371	1968	1285	675	539	361	1481
1941	1327	1097	2009	1769	1652	1057	980	1521	1285	777	483	581	1210
1942	1060	1380	2832	974	981	656	832	1091	1578	1059	525	376	1114
1943	321	1076	1433	1067	1275	990	2210	1530	1827	1532	696	490	1201
1944	534	633	1194	1549	883	705	744	1156	1370	696	434	406	859
1945	477	1452	1272	1896	1878	1149	904	2265	1841	1101	640	524	1279
1946	659	1429	1825	1679	1080	1138	1471	2950	2669	2101	1068	570	1557
1947	543	785	2254	1351	3068	1144	1198	1856	1582	1065	544	345	1300
1948	1527	1452	2050	1758	1229	899	903	2557	3512	1586	968	768	1602
1949	1002	1474	1298	692	1235	1477	1564	3164	2562	1714	1053	761	1501
1950	738	2660	2592	1559	1820	1852	1474	2020	4096	2917	1405	660	1981
1951	1379	2276	3617	1976	3106	1074	1617	2208	2305	1484	720	488	1846
1952	1246	1274	1245	714	1320	763	1281	2238	2110	1701	894	560	1278
1953	387	417	988	4033	2215	950	991	2200	2080	2203	1133	773	1530
1954	1167	2502	3035	2107	3211	1517	1292	2219	2418	2701	1544	980	2051
1955	1307	3560	2062	1124	1259	654	1218	1452	3126	2110	1142	696	1640
1956	1254	3240	1940	1541	746	1005	1731	3333	3754	2802	1288	864	1960
1957	1834	1574	2592	939	1984	1661	1334	2329	1751	1077	654	508	1519
1958	526	769	1428	2560	2549	1264	1125	2413	2160	1060	573	506	1405
Mean	864	1510	1930	1711	1609	1226	1341	2052	2265	1554	828	584	1456

Table 441 --Observed Mean Discharge, in CFS, Dungeness River Near Sequim, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										292	143	94	
1929	185	206	186	133	106	134	201	525	666	447	228	129	263
1930	97	87	187	105	297	211	374	361	486	284	169	134	232
1931	145	146	110	430	328	299	328	546	599	374	182	168	299
1932	142	288	286	278	413	390	391	582	834	504	268	148	380
1933	148	442	326	307	141	224	284	504	932	854	458	282	409
1934	288	319	958	630	390	434	462	528	444	328	201	136	452
1935	258	602	342	726	574	322	261	500	674	488	264	224	458
1936	140	121	180	308	144	244	352	714	769	413	218	152	304
1937	96	72	198	110	109	238	316	612	880	555	228	138	293
1938	156	392	575	393	218	261	438	713	879	537	229	152	413
1939	170	160	256	459	202	229	329	448	454	375	190	125	284
1940	120	168	740	586	397	400	344	666	535	308	188	156	385
1941	348	261	434	393	359	240	276	416	508	344	174	152	325
1942	209	364	715	251	217	163	270	477	638	457	201	120	341
1943	106	225	281	235	255	194	460	449	586	495	231	137	304
1944	149	137	207	195	136	161	185	343	412	220	129	108	199
1945	110	237	219	276	417	231	240	609	579	409	200	150	306
1946	127	214	310	283	194	201	318	684	696	631	324	165	347
1947	133	173	336	269	652	306	347	622	551	346	186	130	336
1948	349	265	414	333	284	214	265	772	1196	584	308	216	434
1949	234	305	333	141	381	318	385	772	697	477	294	225	380
1950	145	597	529	313	379	408	320	598	1103	813	412	201	485
1951	296	550	842	495	754	294	441	641	717	502	243	158	493
1952	242	228	234	133	250	182	377	612	602	527	271	149	317
1953	106	102	174	736	439	209	305	675	689	758	393	233	402
1954	290	581	571	493	815	384	311	638	747	840	521	364	545
1955	429	866	468	259	271	166	265	464	913	652	351	215	443
1956	259	773	460	351	181	213	509	893	1151	837	401	235	522
1957	452	344	524	201	451	387	312	829	642	373	235	180	411
1958	174	174	246	436	583	290	254	869	894	432	223	160	393
Mean	203	313	388	342	346	265	331	602	716	505	264	175	371

Table 442 -Observed Mean Discharge, in CFS, Duckabush River Near Brinnon, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										226	84	62	
1929	205	396	250	186	116	239	232	521	574	294	124	65	259
1930	71	52	276	158	526	259	448	332	329	197	79	66	217
1931	130	172	167	666	406	397	406	490	481	232	86	125	318
1932	152	445	430	351	508	506	488	593	705	378	174	86	403
1933	128	735	383	360	166	274	324	529	832	740	302	296	428
1934	385	457	1388	836	470	536	449	440	294	200	107	73	450
1935	462	1194	536	995	641	368	269	495	546	336	148	186	493
1936	144	134	347	452	248	290	386	688	670	300	119	85	335
1937	55	46	332	115	120	358	418	678	898	442	148	97	328
1938	272	918	810	465	264	385	472	660	676	343	113	68	448
1939	258	301	450	656	220	254	318	411	370	236	97	63	304
1940	89	217	1266	811	588	547	402	584	358	154	82	71	432
1941	513	384	672	569	539	357	374	507	380	180	107	226	400
1942	254	617	951	335	334	162	287	430	486	272	99	58	357
1943	72	413	382	256	334	277	656	396	463	308	115	69	311
1944	321	248	375	452	246	198	232	354	358	145	75	73	257
1945	115	704	342	518	648	300	251	717	499	301	120	119	384
1946	129	474	690	459	326	300	457	810	777	586	240	118	448
1947	136	282	650	292	878	297	290	403	349	180	96	77	324
1948	662	324	521	370	340	223	325	796	861	364	169	208	431
1949	275	400	302	129	375	495	405	728	520	323	156	132	353
1950	132	822	596	351	547	482	398	569	903	592	267	116	480
1951	477	631	1059	470	698	239	484	576	548	287	112	91	471
1952	428	479	349	214	434	240	560	772	626	484	206	97	407
1953	66	155	477	1180	486	283	408	669	584	598	280	183	448
1954	392	967	662	448	868	382	362	546	544	585	303	188	518
1955	400	1254	625	266	330	162	323	412	737	512	234	143	449
1956	329	714	500	451	148	297	626	1043	1088	766	294	182	537
1957	455	348	540	170	541	490	459	742	452	290	163	109	396
1958	266	284	482	711	1015	357	396	720	608	240	102	82	435
Mean	259	486	560	456	445	332	397	587	549	362	157	118	392

Table 443 .--Observed Mean Discharge, in CFS, North Fork Skokomish River Below Staircase Rapids, Near Hoodsport, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										172	69	55	
1929	268	544	363	194	111	306	294	601	598	258	112	58	310
1930	76	49	396	150	686	331	585	333	242	135	64	60	256
1931	154	240	255	922	475	583	611	539	518	216	71	113	391
1932	207	587	585	420	566	661	682	766	835	427	185	85	500
1933	155	926	535	480	186	366	433	699	984	817	308	380	524
1934	494	464	1778	1204	571	661	419	438	184	188	109	86	552
1935	673	1320	665	1235	744	431	338	610	604	334	140	197	606
1936	181	213	583	688	348	406	473	848	771	334	115	82	421
1937	45	40	603	124	128	507	637	923	1091	438	[illegible]	96	399
1938	396	1169	1052	569	267	486	602	727	610	266	[illegible]	61	526
1939	323	467	706	851	283	335	438	489	338	202	[illegible]	60	384
1940	111	335	1604	1007	780	707	501	626	262	119	66	62	516
1941	785	551	857	710	679	495	448	547	284	140	113	275	490
1942	369	694	1166	428	413	228	346	428	506	252	98	56	415
1943	95	582	552	338	381	429	901	475	465	267	108	66	387
1944	321	299	517	646	351	260	318	412	325	126	63	84	310
1945	163	878	448	702	856	325	326	959	504	269	110	145	471
1946	182	628	851	634	450	437	641	1017	881	619	223	120	558
1947	204	460	955	443	1153	408	410	400	314	190	93	84	422
1948	898	455	755	493	365	272	438	1000	974	349	160	280	538
1949	364	514	366	153	386	633	634	1036	639	351	164	148	449
1950	166	1215	929	507	629	620	537	759	1099	661	286	123	626
1951	726	914	1464	617	1087	303	642	663	534	234	100	134	615
1952	599	614	465	290	602	253	639	939	719	497	229	115	496
1953	69	201	576	1915	719	332	472	812	647	589	230	198	564
1954	441	1134	928	571	1016	515	494	674	625	616	250	173	617
1955	519	1655	808	360	430	190	412	525	886	524	224	143	555
1956	564	1131	677	558	182	314	738	1304	1332	915	321	206	688
1957	630	500	826	233	713	632	611	737	369	224	159	104	477
1958	297	398	693	1027	1381	480	525	772	506	178	84	81	530
Mean	349	639	765	616	565	430	518	702	622	358	150	129	487

Table 444 --Observed Mean Discharge, in CFS, White River at Greenwater, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1010	650	430	
1929	380	270	273	252	203	518	490	1220	1360	979	707	376	586
1930	238	173	341	230	877	605	923	847	922	762	615	401	575
1931	321	252	234	605	545	537	819	1390	1020	768	559	365	619
1932	326	503	576	699	811	1150	1040	1350	1720	1160	622	379	861
1933	364	1750	915	853	318	458	749	1230	2380	1900	990	556	1040
1934	946	1009	3648	1693	889	1177	1334	1130	898	761	671	431	1222
1935	656	1359	926	1305	897	633	646	1111	1396	988	646	509	922
1936	299	220	269	618	292	579	1012	1704	1548	881	663	451	713
1937	324	188	388	162	256	537	819	1358	2187	1242	637	485	717
1938	394	1195	992	828	396	488	1106	1531	1812	1116	608	502	916
1939	325	427	583	604	417	641	1009	1325	1163	916	645	406	707
1940	286	299	730	564	679	693	746	1267	1006	753	593	483	675
1941	433	420	631	447	368	398	566	834	890	793	615	426	570
1942	478	603	1060	456	454	352	655	950	1448	1116	710	424	727
1943	303	786	872	584	704	539	1227	1007	1447	1314	673	486	828
1944	357	325	568	349	446	380	542	943	1066	740	543	437	558
1945	309	329	436	869	778	456	632	1625	1427	991	555	410	735
1946	374	644	787	779	516	737	1031	1855	1692	1354	802	469	923
1947	468	710	1462	841	899	735	971	1538	1247	839	576	481	898
1948	1114	1140	800	739	581	499	690	1592	2652	1088	691	467	1004
1949	466	643	649	432	581	762	1121	2280	1762	1128	666	473	915
1950	414	960	769	655	694	924	892	1570	2660	1874	862	552	1070
1951	818	1448	1536	727	1313	624	1169	1504	1484	1129	638	422	1065
1952	556	544	501	330	642	428	970	1407	1249	1004	625	433	724
1953	341	227	243	1043	978	416	665	1149	1302	1404	715	500	747
1954	490	598	1372	647	843	552	690	1352	1416	1531	758	529	900
1955	432	624	514	525	688	320	572	985	2395	1573	846	591	838
1956	863	1592	1490	726	400	457	1260	2225	2200	1791	898	569	1208
1957	520	690	1515	605	535	854	917	1753	1395	817	609	520	897
1958	377	416	648	776	852	504	734	1744	1562	950	720	449	811
Mean	467	690	880	681	644	602	867	1393	1557	1122	682	466	837

Table 445 --Observed Mean Discharge, in CFS, Puyallup River at Puyallup, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										3080	2080	1720	
1929	2100	1510	1590	1710	1620	2820	2800	4960	5130	2690	2130	1600	2560
1930	1160	678	1770	1730	4030	3080	3020	2720	2740	2170	1780	1440	2180
1931	1620	1130	1040	2550	2120	2660	4300	3360	3610	2430	1900	1500	2350
1932	1780	2910	2860	3390	4490	6430	4650	4410	5350	3480	2080	1840	3630
1933	2290	8120	4520	5390	2020	3240	3360	4360	6230	4480	2580	2120	4060
1934	4316	4634	15790	8024	4163	5060	4236	4751	2663	2066	1797	1330	4927
1935	3719	5902	4414	6261	3521	3133	2985	3215	4116	3189	2018	1626	3676
1936	1193	1238	1499	4396	2734	3540	4115	6647	6061	3191	2438	1909	3249
1937	1358	792	3140	1416	2352	2996	4103	4165	6322	3360	2089	1661	2812
1938	1427	6280	5222	4203	2324	2572	4992	4430	4155	2855	1918	1805	3516
1939	1700	2264	3344	3796	3098	3497	3380	3784	3978	3050	2093	1565	2963
1940	1423	1727	3392	3135	4486	3964	3098	3618	2447	2097	1706	1561	2717
1941	1591	2217	2515	2324	1801	1585	1977	2575	2666	2218	1737	1818	2087
1942	2313	2670	4850	2325	2483	1942	2487	3505	5167	3682	2183	1360	2917
1943	1139	4206	4638	2940	4094	2763	4601	3339	4448	3389	1796	1502	3226
1944	1540	1480	3037	2074	2305	2054	2196	3027	2955	2069	1628	1869	2186
1945	1315	1477	2189	4693	3977	2755	3395	4951	3616	2375	1798	2086	2879
1946	1829	4335	4594	5034	4059	4289	4053	5534	5290	3910	2104	1383	3867
1947	2141	3807	7523	4411	4110	3156	3903	3962	3808	2479	1505	1642	3535
1948	3926	5641	4513	4084	3762	3304	3153	5095	6963	3447	2454	1824	4011
1949	2186	3495	4358	1869	3640	3904	4399	6407	4399	3226	2171	1488	3461
1950	2192	4067	4630	4509	5000	5969	4145	4692	6928	5160	2643	1737	4301
1951	3123	5304	6577	4812	7187	3529	3494	4153	3665	2583	1777	1364	3960
1952	2916	2682	2910	1874	3289	2277	3267	4291	3505	2808	1744	1192	2727
1953	846	656	964	6248	5490	2297	2981	3600	4551	3924	2026	1483	2907
1954	1714	2987	7465	4363	4397	3068	3458	3957	4934	4513	2574	1995	3785
1955	1837	2906	2730	3355	3948	2146	3740	3700	6830	4850	2493	1621	3337
1956	3663	6925	7646	4708	2588	3673	4634	5905	6369	4593	2244	1498	4544
1957	2523	3288	6667	2121	2960	4436	3820	4855	3868	2340	1687	1457	3341
1958	1401	2068	3699	4335	4354	2782	3567	4260	3934	2620	1960	1598	3040
Mean	2076	3253	4336	3736	3547	3297	3610	4274	4557	3175	2035	1629	3292

Table 446 --Observed Mean Discharge, in CFS, Green River Near Auburn, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										444	235	211	
1929	573	516	830	675	715	1590	1600	2040	1230	438	226	182	885
1930	198	270	870	560	2170	1780	1850	1150	660	318	165	127	843
1931	263	490	550	1400	1200	1470	2080	1410	450	320	180	192	834
1932	727	1400	1200	2270	2540	4250	2500	1900	1340	520	278	244	1597
1933	646	4340	2150	3240	840	1760	1960	2200	2400	850	247	455	1757
1934	1740	2180	6900	4300	1680	2660	1380	740	355	240	145	175	1875
1935	1240	1900	2170	3550	2050	1600	1320	1480	935	440	244	160	1424
1936	190	453	780	2800	1030	2350	2390	2500	1310	415	567	376	1263
1937	230	187	1757	627	1304	1909	2505	2010	1685	587	287	231	1108
1938	321	3142	2496	2509	1084	1463	2682	1977	728	317	185	144	1421
1939	222	966	1753	2449	1694	1923	1810	1342	1033	486	233	203	1174
1940	327	821	1600	1028	2071	2077	1450	1399	408	223	155	148	972
1941	285	824	1377	1030	732	681	827	676	607	290	182	437	662
1942	1056	1156	2358	981	1350	1137	1457	1266	1849	639	298	196	1143
1943	222	1923	2367	1435	1630	1438	2624	1685	1331	569	238	173	1298
1944	305	521	1631	906	1180	1041	1302	1492	768	303	195	286	827
1945	276	562	1075	2762	2099	1583	2172	2797	1076	362	201	510	1285
1946	734	1946	2040	2432	1776	2442	2453	2665	1710	774	297	239	1625
1947	733	1341	4182	2452	2211	1757	1977	1117	750	453	204	256	1451
1948	1607	3062	1974	1980	1812	1531	1959	2854	2205	707	404	375	1703
1949	643	1568	1945	1000	1875	2042	2409	3018	1318	537	250	187	1396
1950	775	1741	2225	1715	2187	3112	2615	2829	2648	954	340	244	1778
1951	971	2533	2912	2368	4061	1620	2033	1870	847	291	151	132	1632
1952	727	1137	1253	746	1732	1166	1955	1694	734	414	173	108	983
1953	110	111	224	3499	2824	1173	1584	1588	1300	625	279	186	1115
1954	355	1261	4184	2343	2300	1451	2002	1987	1962	917	379	356	1622
1955	400	1085	1118	1563	2272	1020	1889	2308	2759	1274	500	272	1363
1956	1447	2845	3491	2075	1032	1655	2905	3042	1748	680	251	186	1782
1957	825	1302	3586	872	1127	1971	2239	1696	655	346	220	148	1252
1958	217	654	1692	2098	2352	1103	1841	1303	466	217	139	194	1015
Mean	612	1408	2090	1922	1764	1758	1992	1871	1242	517	254	237	1306

Table 447 --Observed Mean Discharge, in CFS, South Fork Skykomish River Near Index, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1310	474	407	
1929	1950	1070	976	595	454	1720	1830	4800	4560	1670	540	350	1720
1930	461	426	1610	770	3970	2090	3360	2650	2340	962	406	380	1600
1931	1280	1160	1010	2140	2040	2720	2620	3700	2810	961	404	597	1790
1932	1210	2460	1460	2210	3930	4060	3690	4340	4660	2350	812	581	2640
1933	1634	7910	3377	2792	780	1719	2645	4119	6860	4682	1693	1962	3352
1934	4326	3786	9440	5334	2262	4278	4244	3158	1627	839	498	588	3383
1935	2610	4132	2843	5093	2651	1630	1641	3688	4322	2072	635	491	2651
1936	528	938	1153	2081	695	1881	3867	7005	5017	1424	535	536	2141
1937	479	365	3092	595	897	1858	2464	4424	6309	2013	687	449	1973
1938	997	4910	3258	2158	802	1551	3725	4169	3352	1122	434	341	2237
1939	740	2398	3151	3524	1394	1986	3322	4827	3730	2364	755	506	2399
1940	1135	2055	3838	1611	2248	2481	2467	3538	1651	655	408	322	1868
1941	1232	1477	1974	1435	1068	1209	1640	2167	1414	646	383	1578	1352
1942	3035	2238	3155	819	1010	1209	2859	3298	3922	1563	557	360	2007
1943	642	3058	2608	1760	1709	2348	4336	3969	4933	3263	898	506	2501
1944	717	1151	2999	1376	1254	1553	2317	3516	2607	889	471	1297	1679
1945	1011	1637	2280	3605	2811	1460	1815	5027	3013	1197	480	1004	2109
1946	1786	2806	2322	2040	1432	1950	3129	6260	5552	2686	782	502	2609
1947	1695	1515	4331	2977	2932	2538	3750	4656	3413	1625	637	704	2564
1948	3539	3590	2778	1655	1559	1283	2383	5797	7130	2327	1095	944	2840
1949	1725	2374	1700	748	1569	2258	3395	6758	4740	2807	1142	952	2518
1950	2273	4104	3047	1942	1899	3131	2777	4579	7966	4926	1757	781	3269
1951	2945	3926	4321	2268	4844	1419	3059	4622	3614	1363	536	589	2775
1952	2682	2048	1386	873	1891	1123	2973	4563	3340	1728	587	376	1962
1953	267	316	892	6868	3375	1398	2410	4057	3860	3172	925	603	2343
1954	1410	2843	4652	2126	2778	1593	2564	4893	5477	5075	2007	1264	3059
1955	1534	3502	1948	1354	2188	913	1964	3710	6865	4643	1663	668	2575
1956	3383	5022	3373	1450	746	1429	4031	6929	6034	4032	948	885	3193
1957	2928	2625	5679	1029	1652	1887	3214	5694	3825	1403	622	403	2588
1958	603	1251	2600	2429	2455	1334	2522	5023	2642	832	434	714	1900
Mean	1692	2570	2908	2189	1976	1934	2900	4531	4250	2176	791	708	2385

AD-A036 573 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

UNCLASSIFIED NL

5 OF 6
AD A036573

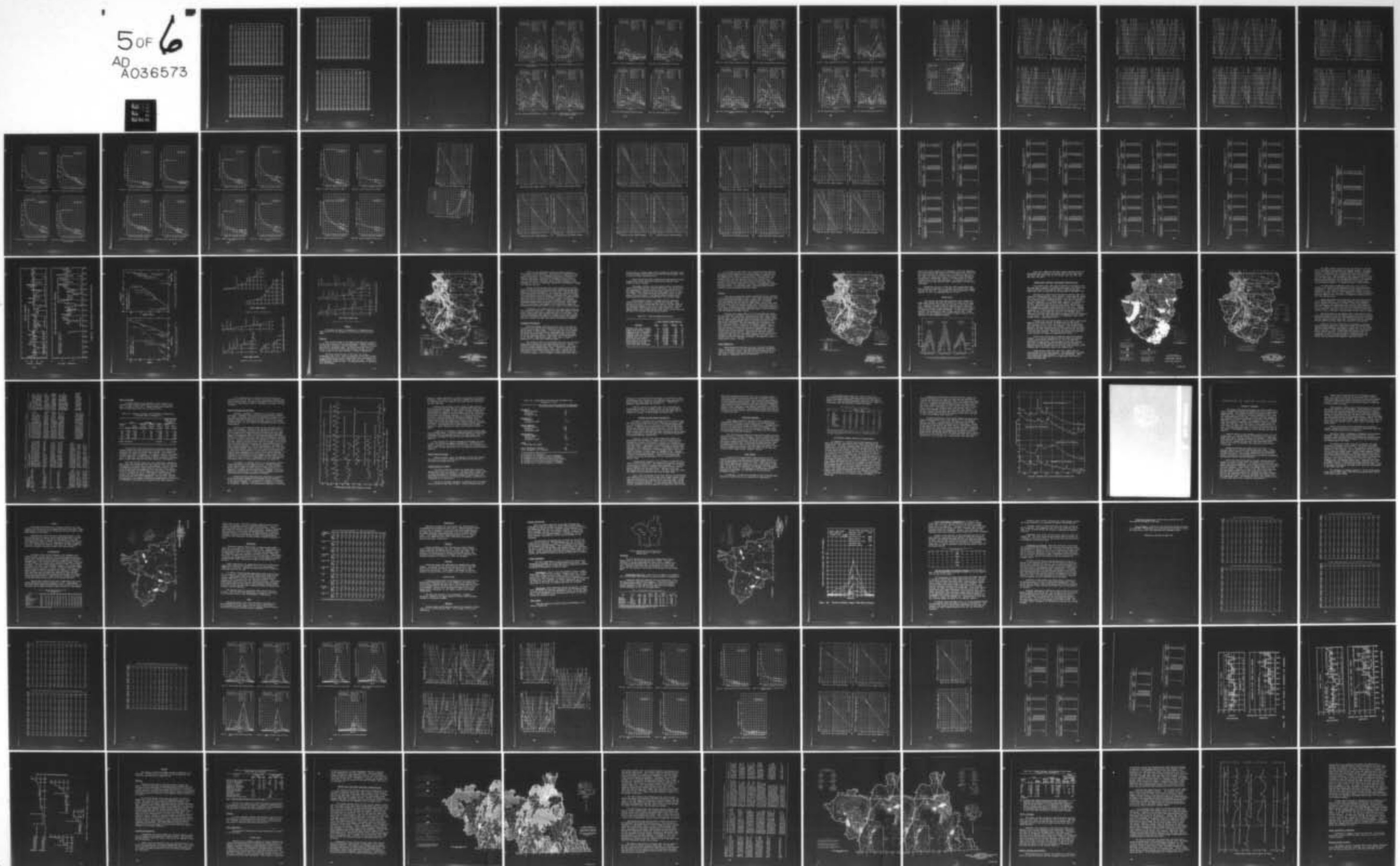


Table 448 --Observed Mean Discharge, in CFS, Snoqualmie River Near Carnation, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1370	589	596	
1929	4470	1980	2140	1260	873	3850	3470	6360	5960	1930	693	521	2810
1930	761	792	3930	1920	6780	3510	4040	3430	3000	963	492	547	2480
1931	2760	2230	1870	5290	3420	4720	4850	4280	3500	1200	509	1250	2990
1932	2830	4400	3530	5180	5540	9980	6800	5620	5450	3320	1340	1180	4590
1933	3080	12800	6640	6960	2380	4360	4060	5730	7740	4000	1420	3020	5190
1934	5760	6712	14530	9550	4003	5122	4244	3178	1567	1067	773	1106	4823
1935	4434	6381	5319	8530	3974	3282	2842	3626	3584	2126	1001	779	3827
1936	994	2681	3199	6055	2207	4228	4934	7847	5570	1881	716	963	3445
1937	871	667	5688	1291	3233	4052	5414	5646	6856	2197	1059	794	3144
1938	1909	8851	6019	4814	2065	2946	5962	4585	2780	1090	583	493	3509
1939	1196	3942	6105	6376	3516	3711	4112	5031	4906	2811	902	851	3624
1940	2325	3509	6277	3019	4640	5089	4043	4422	1803	840	626	517	3091
1941	2012	2925	3894	2941	2001	1933	2230	3072	2250	966	523	3032	2314
1942	4309	3401	5929	2222	2648	2646	3677	4117	6035	2206	899	576	3224
1943	1018	6979	6000	3110	3772	3638	5546	4921	4881	2713	1023	791	3689
1944	1869	2101	5123	2511	2658	2721	3869	5224	3263	1153	734	2563	2815
1945	1664	3402	3883	6161	4860	3740	4144	6588	3626	1472	615	2574	3551
1946	3309	6693	4835	4861	3862	4315	4655	6333	6233	3081	1028	811	4166
1947	3059	4081	8690	6198	5674	3833	5601	4265	3994	1846	899	1614	4137
1948	5811	8282	5634	4632	3981	3207	4037	7238	7372	2740	2015	1933	4737
1949	2739	5494	4168	2118	4264	4546	4747	7191	4541	3087	1528	1228	3798
1950	3520	5279	5427	4729	5545	7093	5235	5872	7850	4410	2133	1109	4844
1951	4281	6642	7502	5203	9219	3012	3800	4955	3524	1376	578	719	4200
1952	4374	3424	3362	2098	4030	2686	4392	5578	3884	2327	790	593	3124
1953	479	619	1756	1140	6169	3012	4413	5302	4703	2955	1126	871	3533
1954	2518	5133	9176	5017	6044	3181	3962	4856	6254	4221	2030	2150	4535
1955	1843	4716	3518	3172	4684	2212	4208	5676	7871	5629	2226	1125	3894
1956	5444	7885	7906	4544	2279	3817	5704	7103	6273	3698	1138	1436	4777
1957	4722	4558	8388	2116	3674	4287	4929	5701	3452	1534	910	576	3742
1958	1026	2625	4547	5208	4974	2446	4022	4152	2246	895	517	1170	2805
Mean	2846	4639	5500	4274	4099	3872	4465	5263	4699	2324	1028	1230	3714

Table 449 --Observed Mean Discharge, in CFS, South Fork Stillaguamish River Near Granite Falls, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										344	117	153	
1929	1220	668	724	349	163	1010	945	1570	1320	375	156	100	721
1930	256	203	1170	458	2230	980	1080	808	796	253	91	231	702
1931	917	616	739	1890	943	1600	1430	1020	1230	340	111	738	964
1932	863	1440	1290	1360	2310	2220	1920	1430	1350	1000	295	319	1310
1933	1010	3330	1640	1580	560	1260	1130	1570	2010	1190	454	1140	1410
1934	1596	1326	3917	2641	1006	1819	969	1067	436	367	161	496	1325
1935	1172	2197	1512	2931	1080	898	751	1107	1025	610	253	368	1160
1936	382	720	842	1396	642	1142	1582	2118	1373	458	171	310	929
1937	247	162	2104	243	589	1136	1573	1474	1908	481	267	148	862
1938	871	2477	1812	1175	450	821	1632	1222	586	205	78	78	952
1939	857	1379	1893	1926	675	902	1319	1631	1166	831	201	210	1086
1940	853	1127	2021	888	1439	1456	1010	901	318	140	142	99	865
1941	1116	1053	1272	968	580	514	454	988	427	146	98	902	711
1942	1384	1162	1536	513	673	737	1057	1033	1413	584	146	92	861
1943	431	1779	1468	771	1048	1065	1511	1158	994	703	217	161	939
1944	650	657	1324	960	653	798	959	1236	615	207	131	907	759
1945	755	1431	907	2037	1320	1037	915	1598	767	300	110	640	983
1946	1268	1583	1386	1575	1129	1199	1461	1741	1628	684	230	200	1174
1947	1191	1322	2140	1573	1652	982	1452	1042	1056	450	209	416	1120
1948	1878	1411	1684	1040	1078	694	1208	1932	1560	486	533	800	1192
1949	821	1490	928	386	1148	1291	1440	2013	1162	902	426	562	1045
1950	1360	2114	1918	1292	1855	1960	1530	1568	2007	1028	646	352	1466
1951	1557	1788	2112	1387	3216	746	1055	1176	683	264	136	375	1194
1952	1609	1043	799	697	1178	599	1216	1465	1045	509	221	177	878
1953	164	297	944	4093	1545	785	1131	1357	1074	700	356	601	1087
1954	1316	1594	2441	1307	1915	752	1159	1402	1681	1150	679	687	1336
1955	750	2174	1211	777	1212	454	1214	1597	2079	1425	590	288	1144
1956	2097	2224	1737	1193	450	856	1401	1665	1543	812	258	558	1235
1957	1729	1236	2668	466	1387	1209	1455	1494	931	454	259	149	1119
1958	504	848	1505	1592	1422	654	1115	941	579	210	114	417	821
Mean	1027	1362	1588	1315	1186	1053	1236	1377	1159	575	253	407	1045

Table 450 --Observed Mean Discharge, in CFS, North Fork Stillaguamish River Near Arlington, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										550	235	256	
1929	1750	1470	1300	783	467	1900	1830	2340	1730	559	305	222	1230
1930	334	268	1770	929	3620	1730	1970	1160	956	381	212	363	1120
1931	1310	1050	1380	3370	1940	2850	2700	1530	1590	602	240	1290	1650
1932	1330	2390	2370	2450	3230	4170	3390	2210	1930	1460	483	359	2140
1933	1290	5160	3100	2840	1290	2540	1950	2570	2890	1640	621	1310	2270
1934	2635	2088	5734	4435	1928	2692	1736	1534	643	613	330	566	2088
1935	1385	3439	2547	4655	2326	1697	1253	1613	1324	720	383	568	1824
1936	553	1132	1394	2839	1232	2200	2330	2946	2014	659	299	442	1505
1937	321	223	2950	484	1110	2101	2698	2243	2793	715	470	302	1368
1938	1217	4213	3644	2648	1050	1735	2890	2009	789	332	166	140	1739
1939	1134	2304	3072	3488	1545	1725	2116	2175	1568	939	351	315	1731
1940	1146	2071	3797	1873	2671	2823	1659	1532	525	290	266	216	1571
1941	1651	1719	2369	1852	1190	985	812	1473	706	336	225	1345	1223
1942	1997	2168	3225	1139	1343	1355	1607	1568	2326	849	329	205	1510
1943	726	3185	3015	1740	2209	1635	2922	1991	1723	1020	369	255	1725
1944	858	994	2104	2298	1543	1574	1575	1733	911	359	252	1187	1282
1945	1076	2341	1529	3464	2204	1788	1771	2691	997	496	308	868	1624
1946	2275	2986	2309	2673	2270	2512	2648	2764	2554	1111	436	370	2073
1947	1652	1679	3611	3115	3055	1922	2489	1512	1542	788	387	719	1866
1948	2892	2902	3219	2204	1932	1463	1932	3356	2347	836	827	1191	2093
1949	1581	2736	1895	871	2227	2663	2547	3638	1820	1192	686	677	1874
1950	1868	3572	3606	2323	3396	3425	2645	2453	3088	1522	888	573	2439
1951	2493	3181	4368	2493	4826	1558	1998	2055	1079	489	271	415	2084
1952	2509	1858	1807	1394	2555	1317	2221	2247	1438	699	379	409	1565
1953	283	447	1680	5852	3198	1554	1827	2057	1528	918	492	672	1703
1954	2122	2839	4723	2592	3787	1593	2317	2375	2514	1611	926	1019	2359
1955	1109	3474	2198	1704	2440	1208	2491	2480	3159	1953	874	418	1950
1956	2876	3750	3310	2502	910	1684	2516	2781	2488	1185	454	805	2104
1957	2999	2023	4686	1041	2344	2379	2383	2212	1236	639	452	275	1890
1958	591	1350	2538	3189	3046	1348	1865	1356	737	374	231	488	1416
Mean	1532	2300	2842	2441	2229	2005	2170	2153	1698	843	430	599	1770

Table 451 --Observed Mean Discharge, in CFS, Sauk River Near Sauk, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										4460	2000	1410	
1929	3490	1980	1930	1280	793	2180	2630	6650	7810	4450	2210	1220	3070
1930	993	724	2290	1310	5620	2960	5260	4580	5670	4130	1960	1400	3050
1931	2090	1700	1740	4300	3390	4050	4250	6830	7230	3700	1820	2150	3600
1932	1990	3730	3110	3040	6090	5690	5510	6750	8990	6040	2970	1700	4620
1933	2830	9590	5140	3890	1760	3000	3620	5600	10800	10100	5070	3860	5450
1934	6203	5819	11580	8136	4287	6303	7375	7305	5519	3934	2422	1897	5919
1935	3281	6944	4353	8381	4722	2762	2386	5376	7606	5465	2502	2040	4650
1936	1424	1468	1842	3220	1539	2948	5311	10040	9904	4348	2148	1645	3824
1937	1183	751	3923	1214	1332	2903	3710	6437	11430	5935	2209	1498	3553
1938	2327	6031	5399	4204	1891	2638	4947	6921	7940	4268	1758	1426	4154
1939	1976	2753	4234	5542	2353	2834	4816	7805	7171	6420	2823	1589	4209
1940	2200	3183	6585	3480	3512	4148	3784	6166	4469	2522	1718	1371	3600
1941	3034	2697	3906	2665	2106	2168	2860	4162	3715	2515	1778	2991	2887
1942	4262	3693	5692	1882	1920	1863	3569	5033	6933	4742	1988	1089	3566
1943	1136	3672	4283	2871	3386	3410	6216	5448	7964	7785	2961	1653	4232
1944	1743	1877	3444	2620	2187	2175	2912	5321	5679	2970	1719	2412	2922
1945	2534	3047	2816	4655	4689	2765	2701	7092	6098	4143	1909	2132	3709
1946	3372	4497	3458	3691	2648	3290	4310	9104	8635	6386	2761	1547	4487
1947	2706	2624	5429	3785	4704	3470	4798	7983	7149	4821	2330	1751	4295
1948	4432	4053	4233	3470	2875	2366	3472	8411	12610	5533	3469	2703	4811
1949	3178	3459	2760	1464	2649	3881	4867	10570	8217	6206	3241	2540	4430
1950	3718	8028	5642	3904	4153	5395	4254	6189	12430	10310	4811	2175	5923
1951	4647	6135	7418	4122	9062	2775	4777	7442	7628	4757	2215	1853	5206
1952	4164	3209	2760	1695	3491	1798	4431	7188	6590	5043	2347	1511	3684
1953	1089	886	1457	7956	5615	2465	3393	6029	6216	7174	3492	2280	4000
1954	3152	4284	6140	3929	5686	3049	3707	7119	8471	10140	5452	3583	5394
1955	2942	6513	3832	2532	3083	1523	3311	5212	11480	9099	4173	2070	4648
1956	5580	7752	5055	3273	1627	2328	4970	9054	9709	8068	3122	2562	5267
1957	4780	3832	6922	2238	3594	3696	4175	9197	7326	3975	2211	1648	4476
1958	1704	2040	3213	4275	3945	2412	3369	8134	6741	3195	1882	2115	3583
Mean	2939	3899	4353	3634	3490	3108	4190	6968	7938	5606	2716	2014	4241

Table 452 --Observed Mean Discharge, in CFS, Nooksack River at Deming, Wash.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										2470	1340	1260	
1929	3030	2200	1930	1460	965	2730	2900	4800	4660	2530	1510	1220	2390
1930	1060	900	2560	1630	4860	2500	3070	3040	3230	2120	1290	1400	2220
1931	2420	1570	2040	4400	2570	4050	3930	4020	4400	2630	1360	2550	3040
1932	2450	3580	3370	3360	4330	5870	4750	4600	5030	4610	1930	1390	3790
1933	2390	7210	4350	3800	1690	3620	3040	5140	6800	5030	2250	2580	3990
1934	4260	3120	7880	5610	2550	3830	4380	3600	2660	2660	1570	1650	3710
1935	2520	5140	3610	5860	3100	2450	2220	3710	3910	2659	1400	1957	3300
1936	2042	1903	1997	3727	1349	3228	4861	6750	5266	2525	1450	1594	3063
1937	1104	672	4528	957	1504	3163	3491	4643	7815	3281	1720	1226	2848
1938	2781	6405	5039	3532	1600	2110	3519	3914	3640	2483	1317	1176	3133
1939	1543	2238	4966	5098	2123	2447	3492	4716	4536	3778	1895	1222	3183
1940	2624	3322	6376	2932	3568	4409	2776	3767	2368	1652	1334	1186	3030
1941	2841	2026	3521	2947	2395	2063	1924	3135	2463	1862	1339	2789	2444
1942	4102	3714	4173	1688	1635	1784	2368	2950	4227	2730	1584	963	2667
1943	1091	3348	4054	2607	2988	2264	5011	4040	4511	4023	1715	1300	3075
1944	1723	1370	3233	2771	1701	1990	2283	3372	3142	1798	1324	1983	2227
1945	1751	3276	2430	4456	3179	2472	2619	5480	3617	2696	1490	1748	2934
1946	4102	5010	3481	3558	3007	3098	3725	6123	5327	3761	1949	1245	3703
1947	2331	2099	4459	3435	4420	2974	3774	4413	4030	2564	1348	1495	3104
1948	4815	3921	4752	3542	2505	2063	2636	5637	6550	3027	2742	2587	3736
1949	2800	4063	2523	1430	2731	3706	4029	6109	4538	3405	2201	2161	3309
1950	2405	4462	4931	3146	3817	4782	3631	4630	7207	4963	2668	1864	4041
1951	3856	4175	6244	4247	7118	2284	3205	4067	3458	2366	1432	1218	3617
1952	3316	2509	2416	1560	3193	1828	3590	5260	4158	3160	1855	1252	2839
1953	895	901	1760	6941	4385	2290	3041	4365	4056	3811	1978	1847	3017
1954	3923	5616	6552	4055	5229	2622	2930	4694	5568	5288	3319	2371	4342
1955	2608	6986	3409	2656	2686	1609	3069	4238	7228	5365	2817	1716	3696
1956	3779	5967	4063	3032	1473	2368	4061	5993	7091	4152	2133	1950	3841
1957	5835	3517	5801	1791	2595	3723	3464	5496	3751	2632	1870	1569	3516
1958	1730	1680	2790	4340	4600	2260	2700	4360	3330	2109	1334	1551	2732
Mean	2738	3430	3975	3352	2996	2886	3350	4569	4619	3189	1804	1692	3217

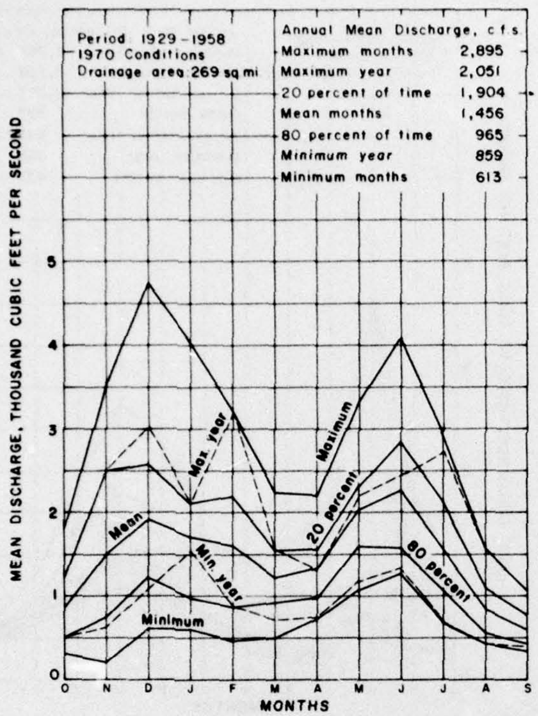


Figure 779 Monthly discharge, Elwha River at McDonald Bridge near Port Angeles.

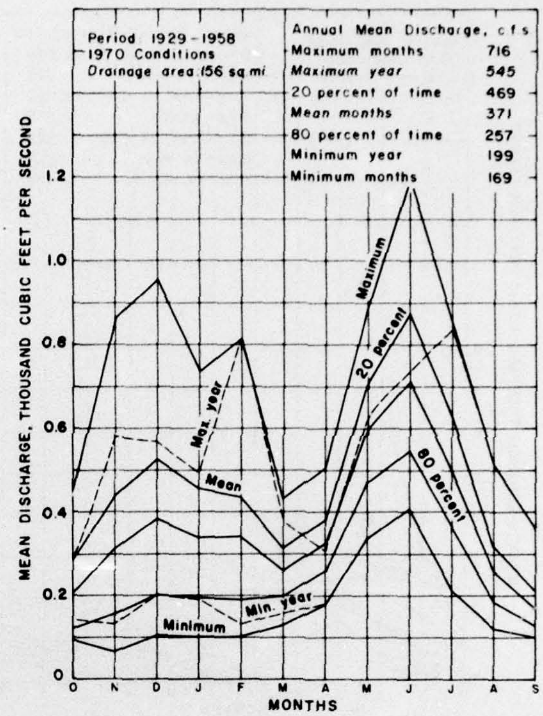


Figure 780 Monthly discharge, Dungeness River near Seqium.

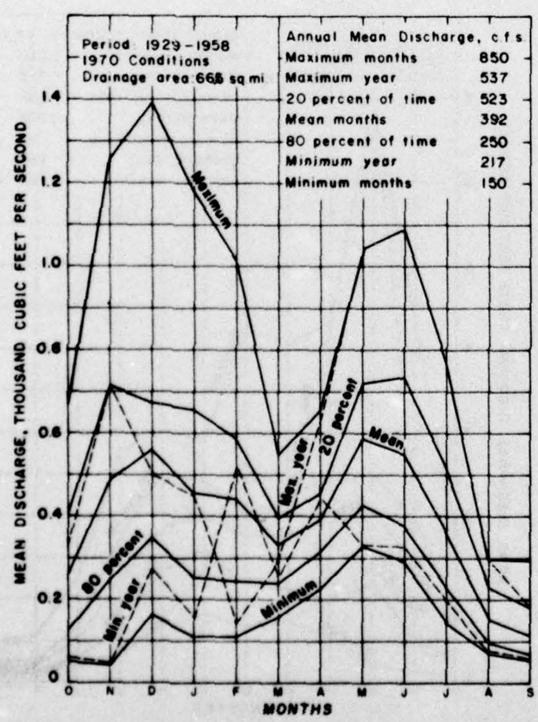


Figure 781 Monthly discharge, Duckabush River near Brinnon.

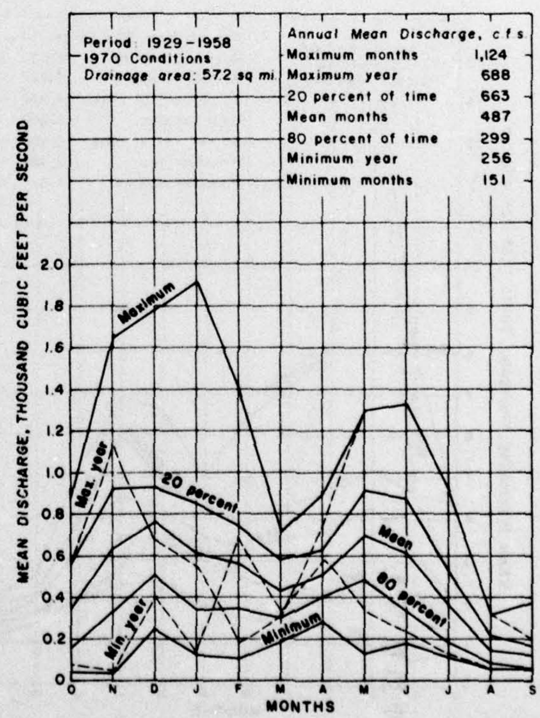


Figure 782 Monthly discharge, N. F. Skokomish River below Staircase Rapids near Hoodsport.

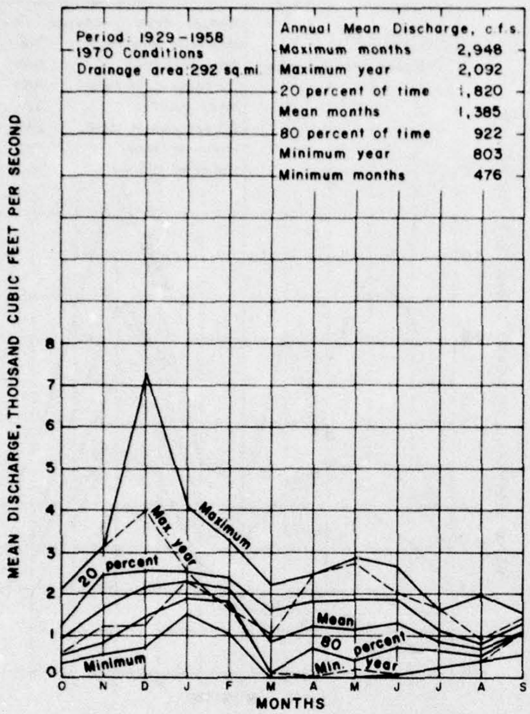


Figure 783 Monthly discharge, Nisqually River at LaGrande.

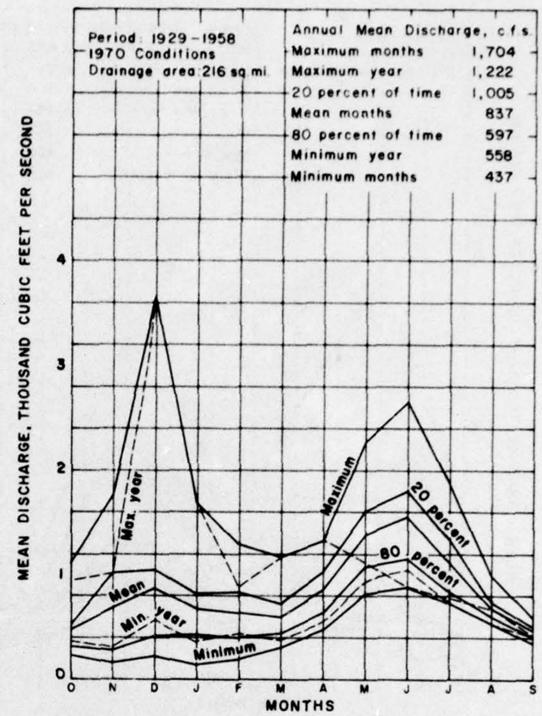


Figure 784 Monthly discharge, Green River at Greenwater.

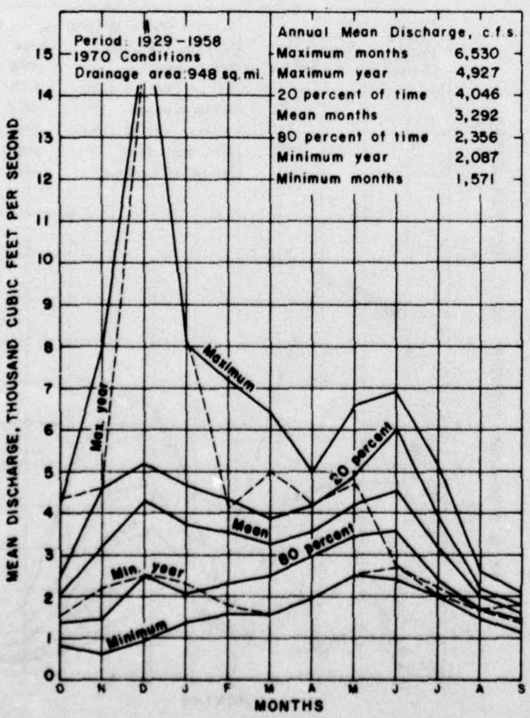


Figure 785 Monthly discharge, Puyallup River at Puyallup.

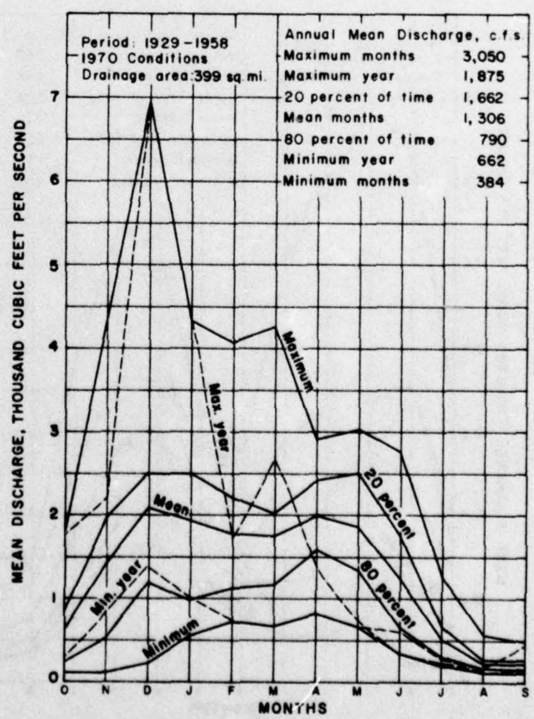


Figure 786 Monthly discharge, Green River near Auburn.

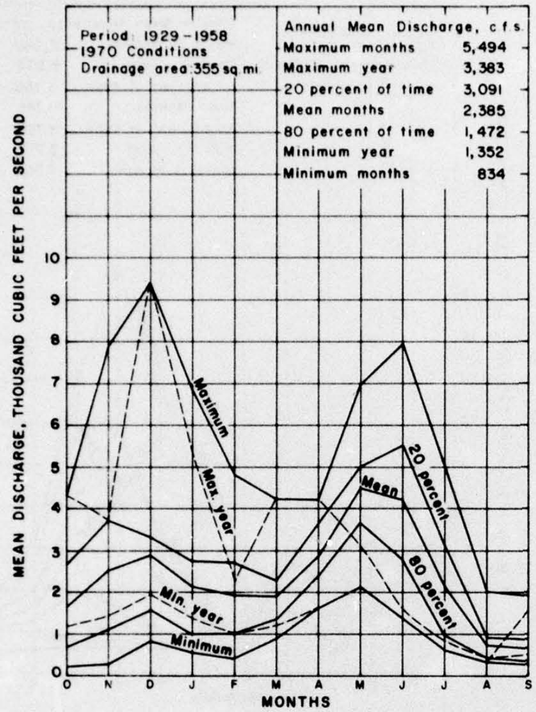


Figure 787 Monthly discharge, S. F. Skykomish River near Index.

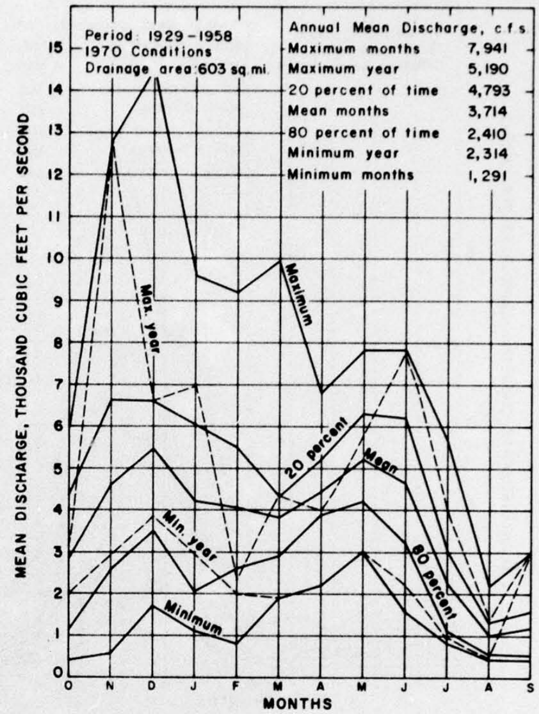


Figure 788 Monthly discharge, Snoqualmie River near Carnation.

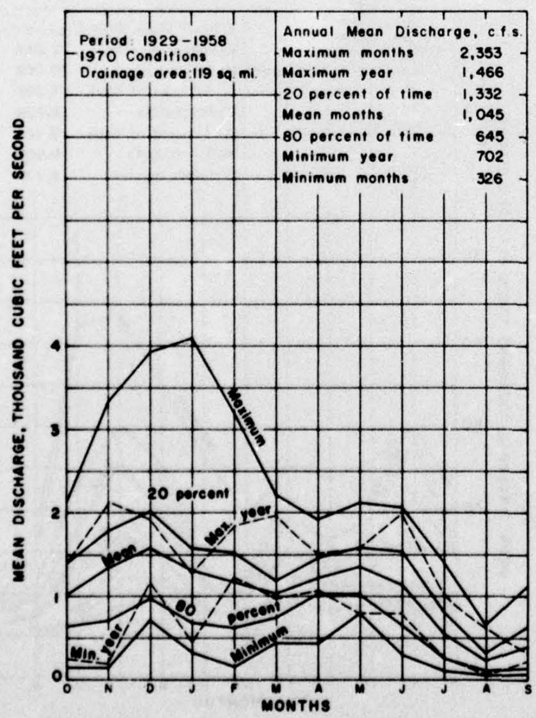


Figure 789 Monthly discharge, S. F. Stillaguamish River near Granite Falls.

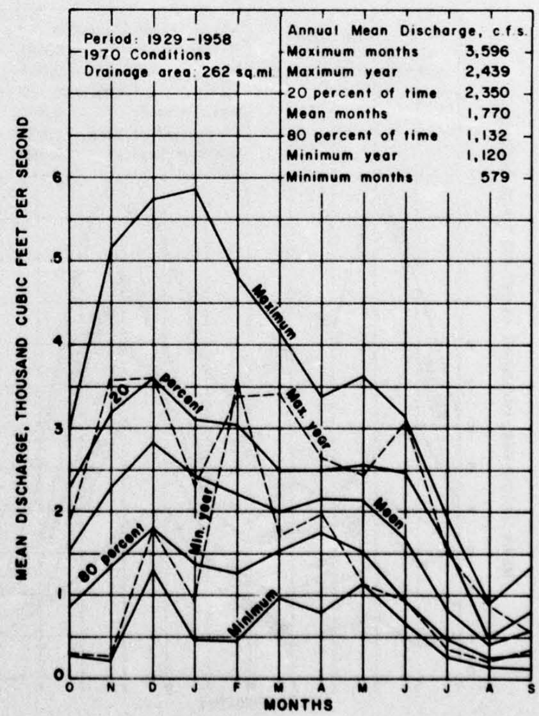


Figure 790 Monthly discharge, N. F. Stillaguamish River near Arlington.

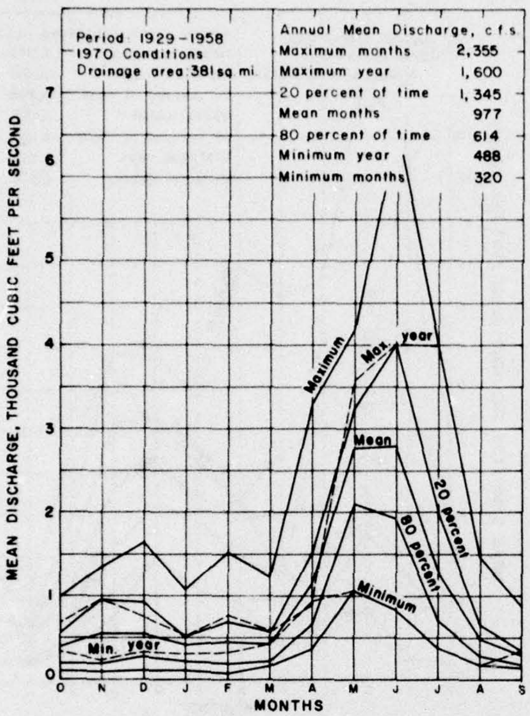


Figure 791 Monthly discharge, Skagit River near Hope, B. C.

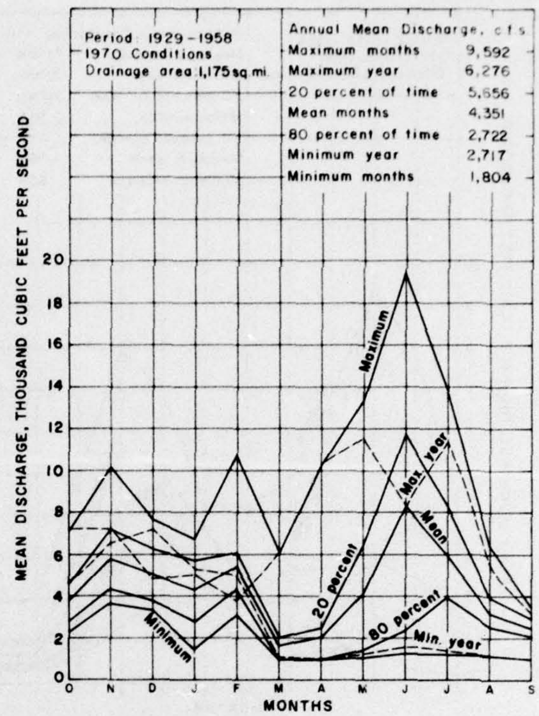


Figure 792 Monthly discharge, Skagit River at Newhalem.

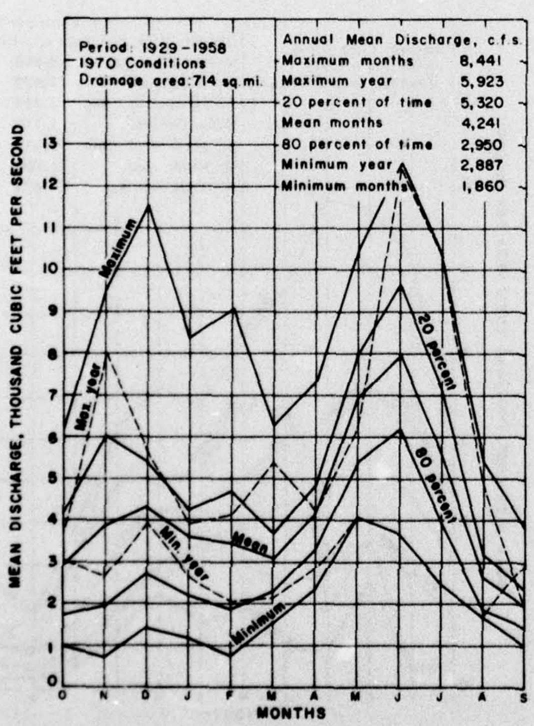


Figure 793 Monthly discharge, Sauk River near Sauk.

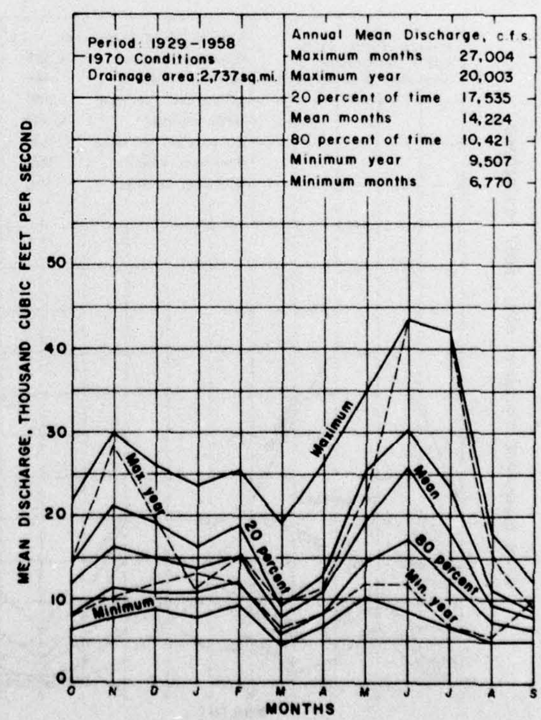


Figure 794 Monthly discharge, Skagit River near Concrete.

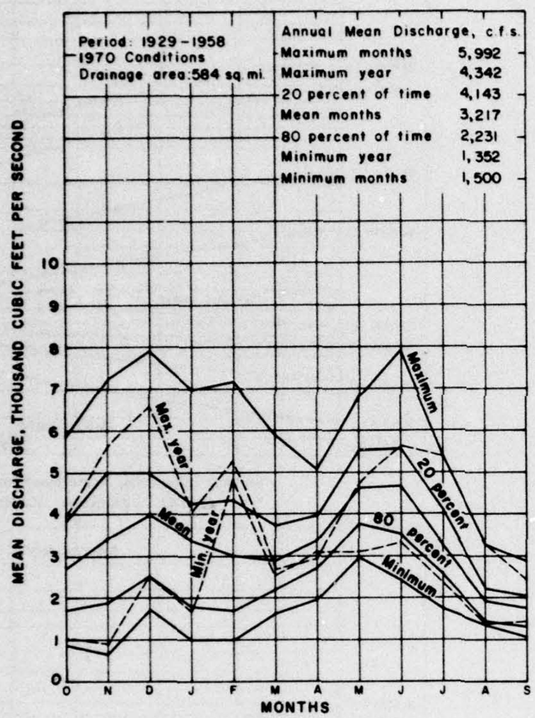


Figure 795 Monthly discharge, Nooksack River at Deming.

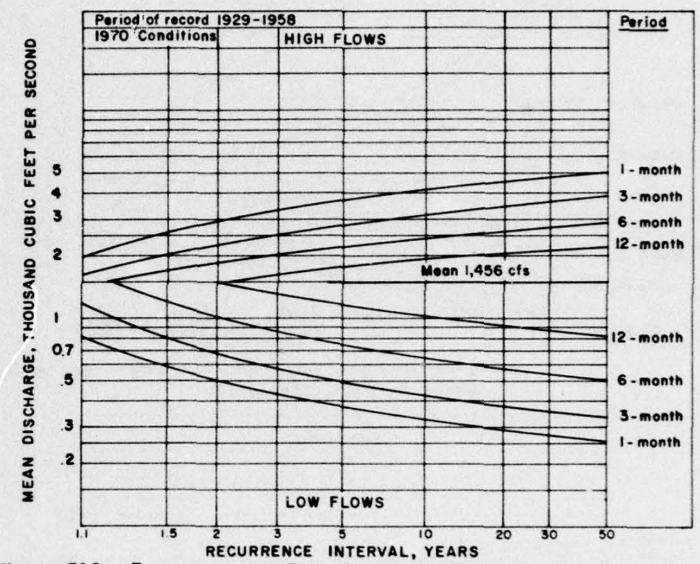


Figure 796 Frequency curves, Elwha River at McDonald Bridge near Port Angeles.

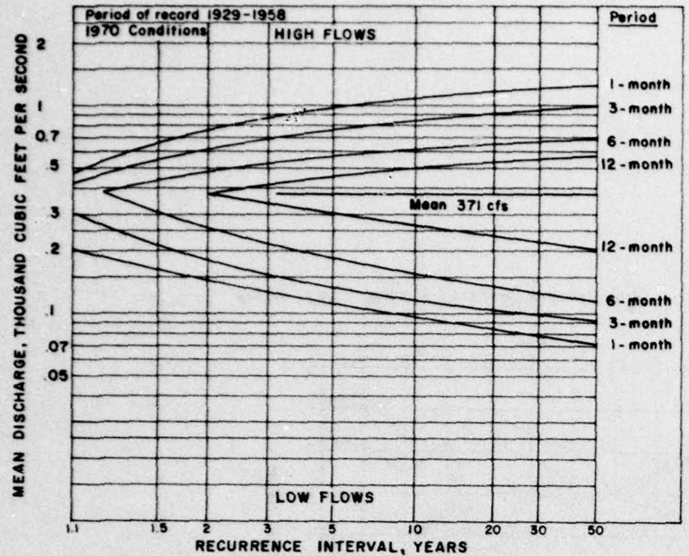


Figure 797 Frequency curves, Dungeness River near Sequim.

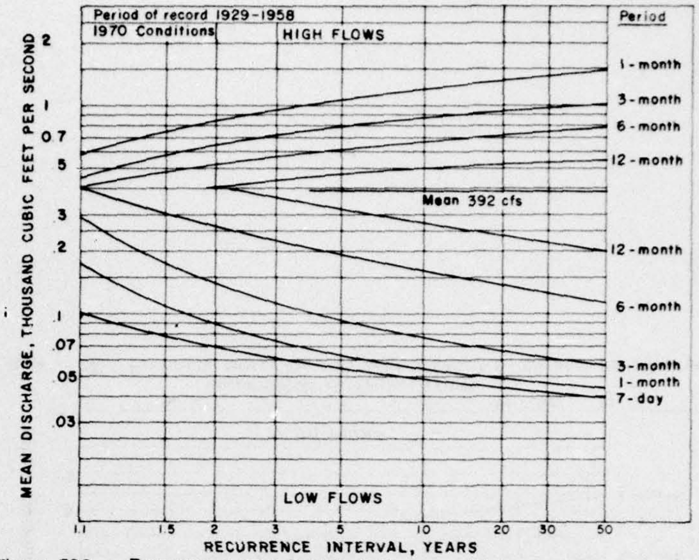


Figure 798 Frequency curves, Duckabush River near Brinnon.

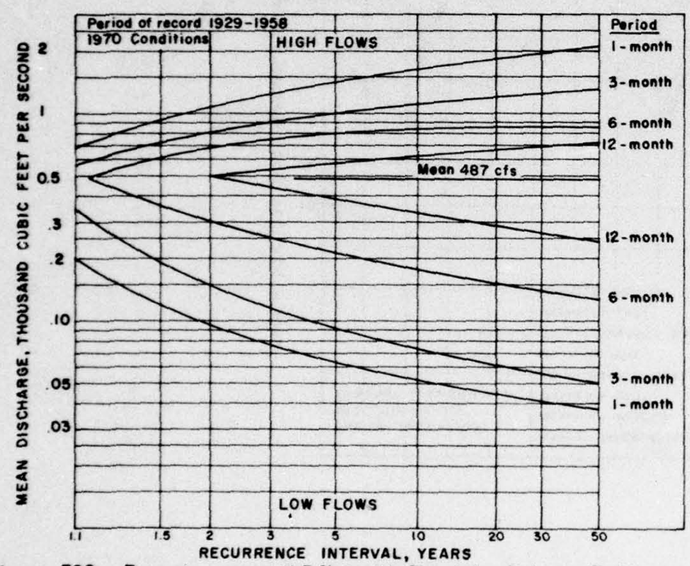


Figure 799 Frequency curves, N. F. Skokomish River below Staircase Rapids near Hoodsport.

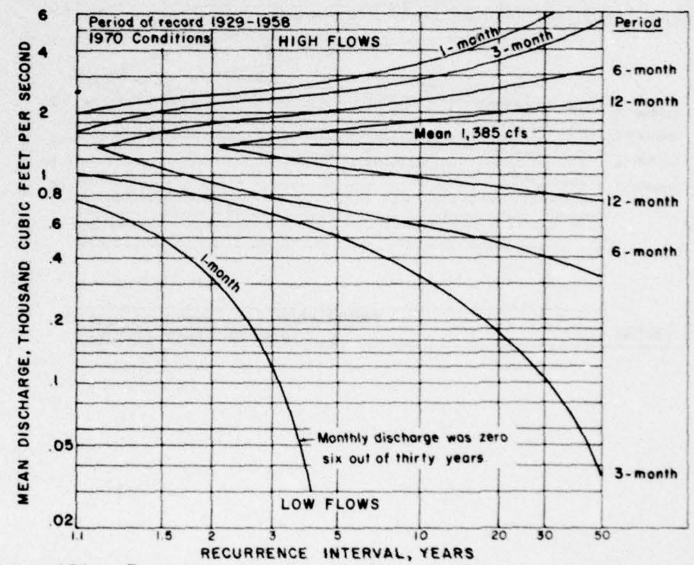


Figure 800 Frequency curves, Nisqually River at LaGrande.

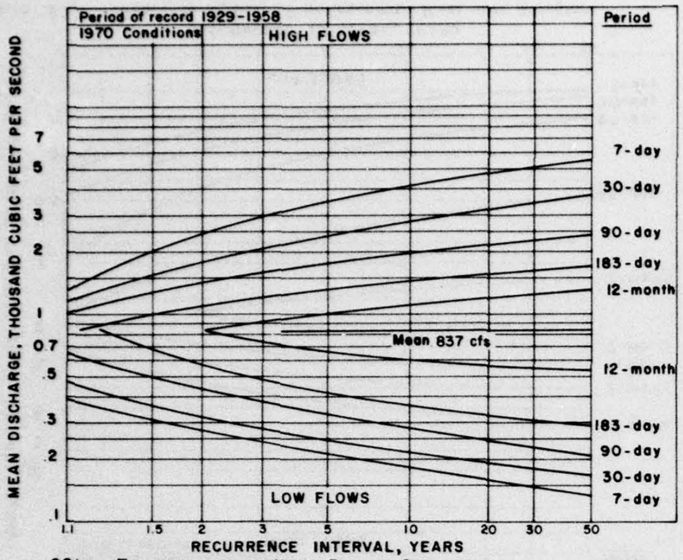


Figure 801 Frequency curves, White River at Greenwater.

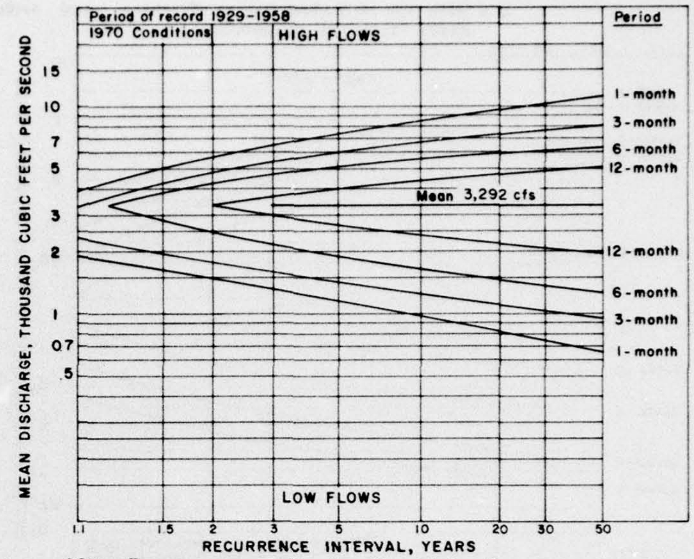


Figure 802 Frequency curves, Puyallup River at Puyallup.

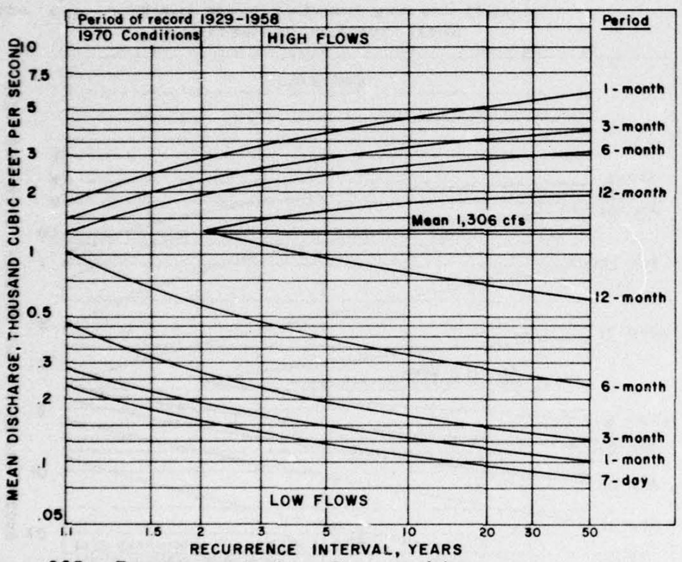


Figure 803 Frequency curves, Green River near Auburn.

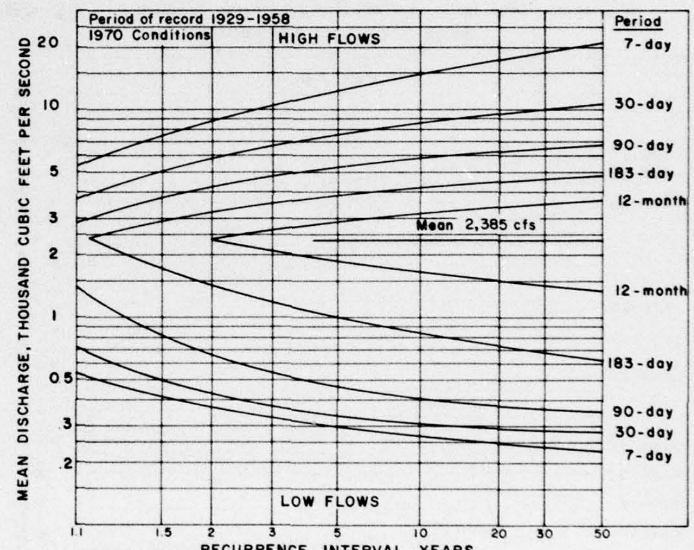


Figure 804 Frequency curves, S.F. Skykomish River near Index.

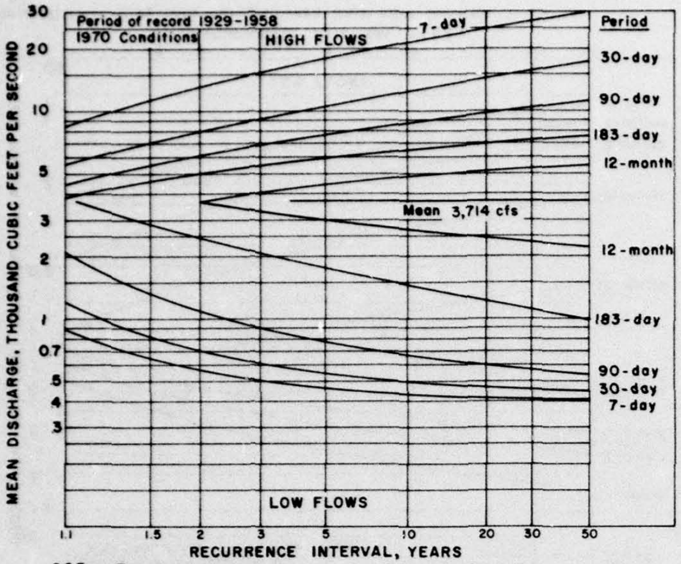


Figure 805 Frequency curves, Snoqualmie River near Carnation.

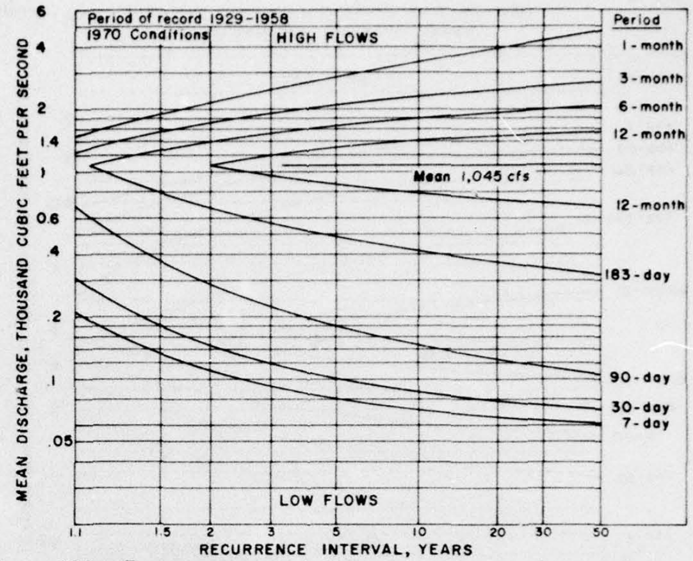


Figure 806 Frequency curves, S.F. Stillaguamish River near Granite Falls.

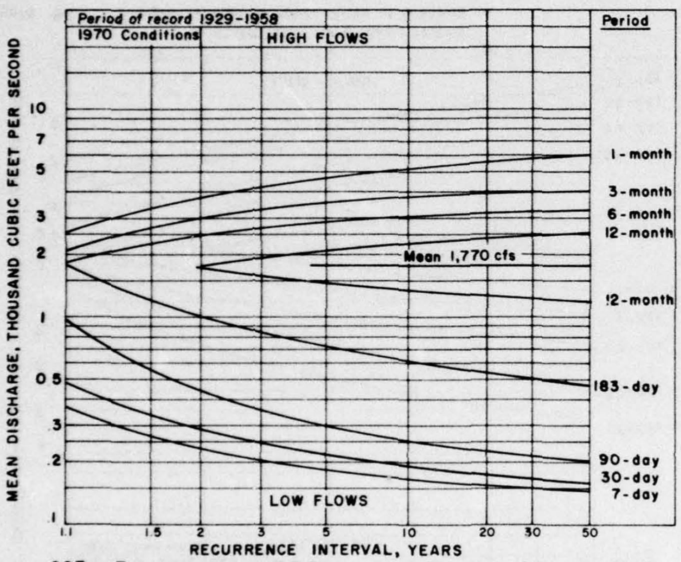


Figure 807 Frequency curves, N.F. Stillaguamish River near Arlington.

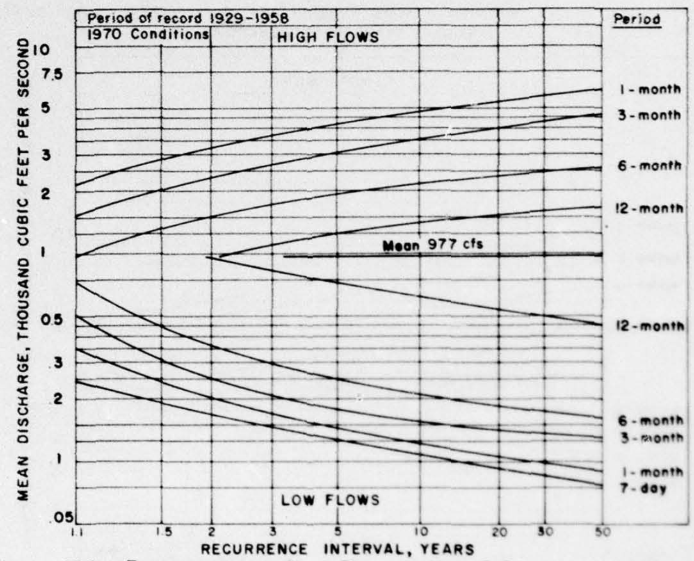


Figure 808 Frequency curves, Skagit River near Hope, B. C.

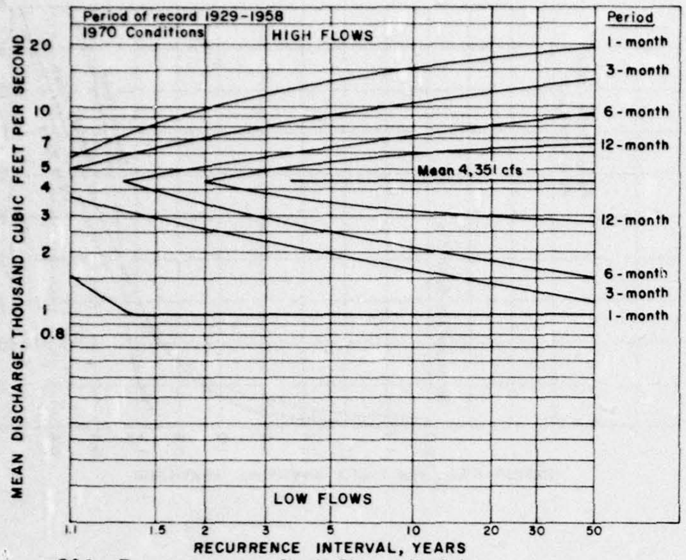


Figure 809 Frequency curves, Skagit River at Newhalem.

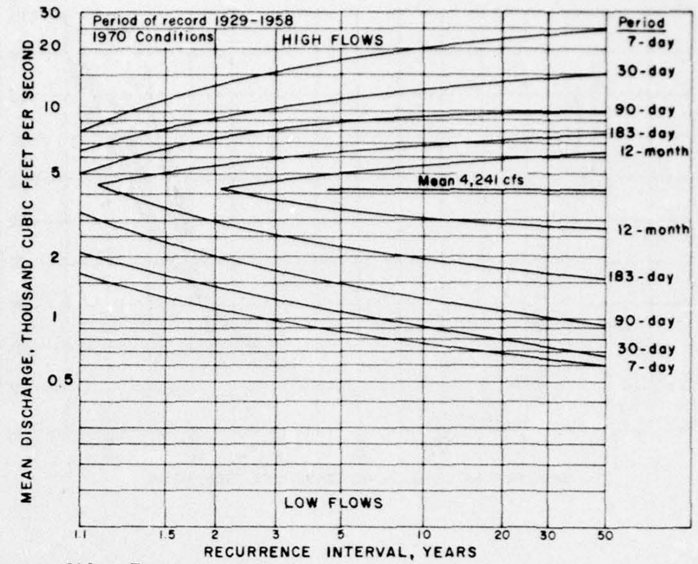


Figure 810 Frequency curves, Sauk River near Sauk.

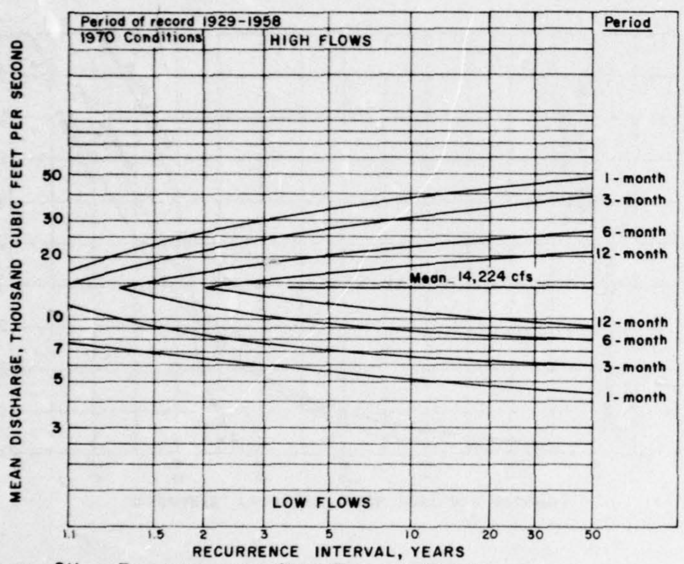


Figure 811 Frequency curves, Skagit River near Concrete.

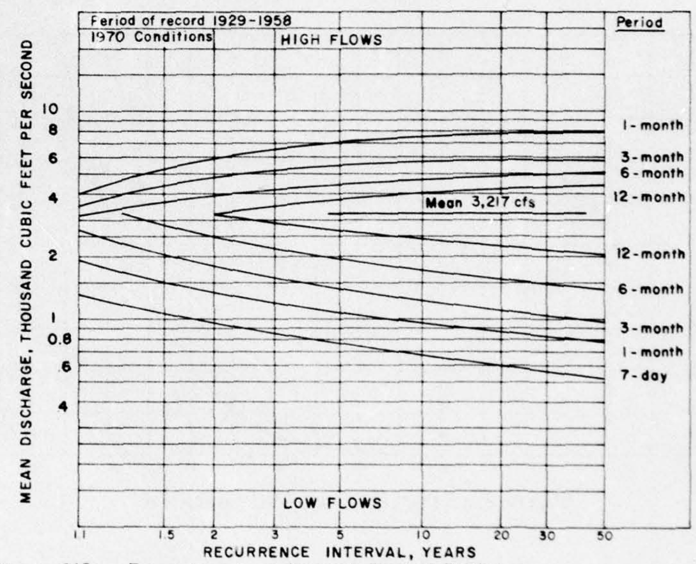


Figure 812 Frequency curves, Nooksack River at Deming.

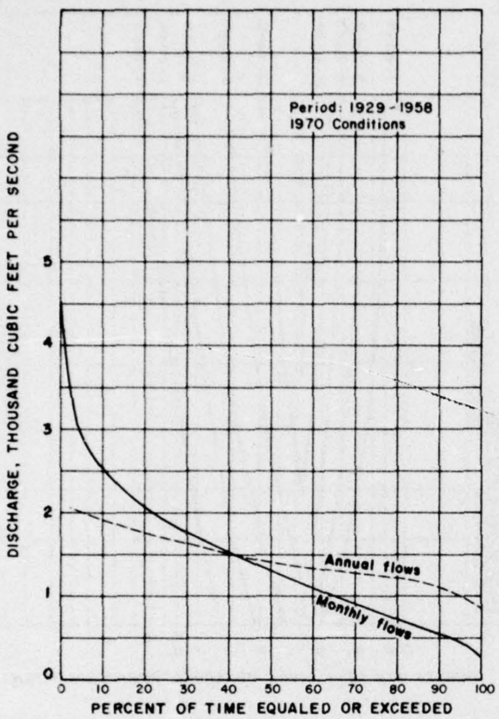


Figure 813 Duration curves, Elwha River at McDonald Bridge near Port Angeles.

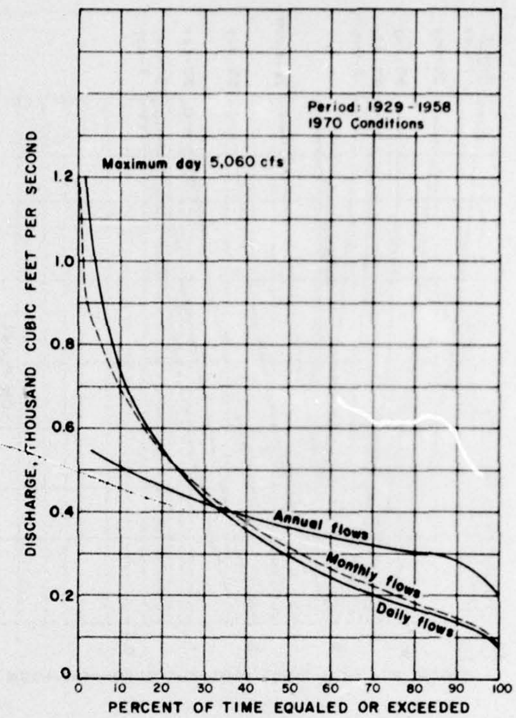


Figure 814 Duration curves, Dungeness River near Seqium.

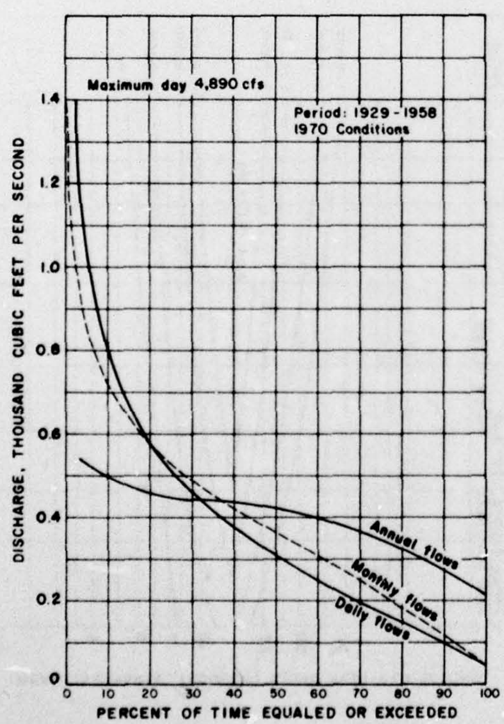


Figure 815 Duration curves, Duckabush River near Brinnon.

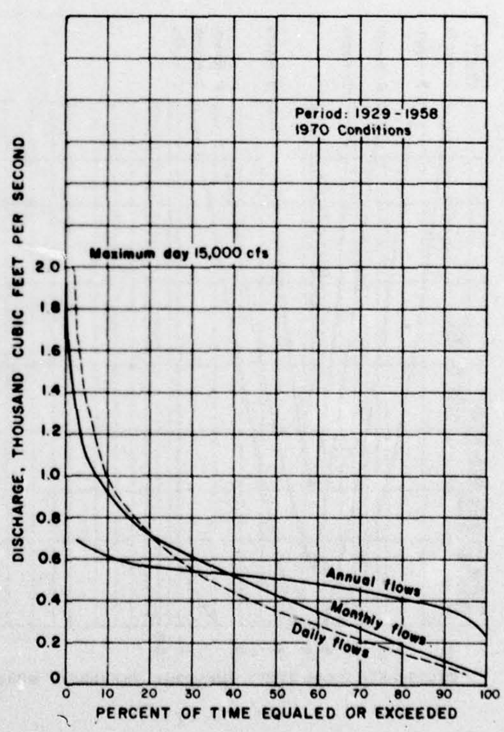


Figure 816 Duration curves, N.F. Skokomish River below Staircase Rapids near Hoodsport.

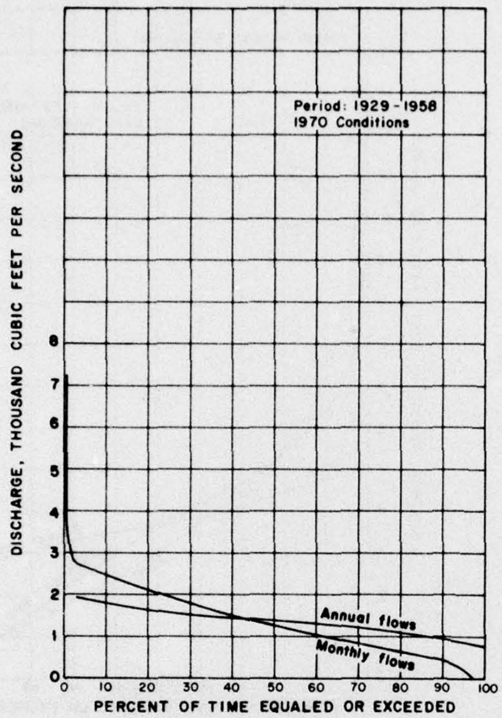


Figure 817 Duration curves, Nisqually River at LaGrande.

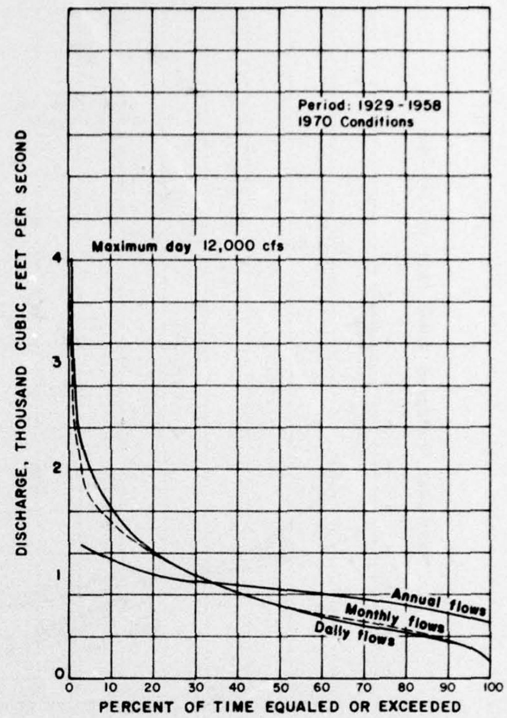


Figure 818 Duration curves, White River at Greenwater.

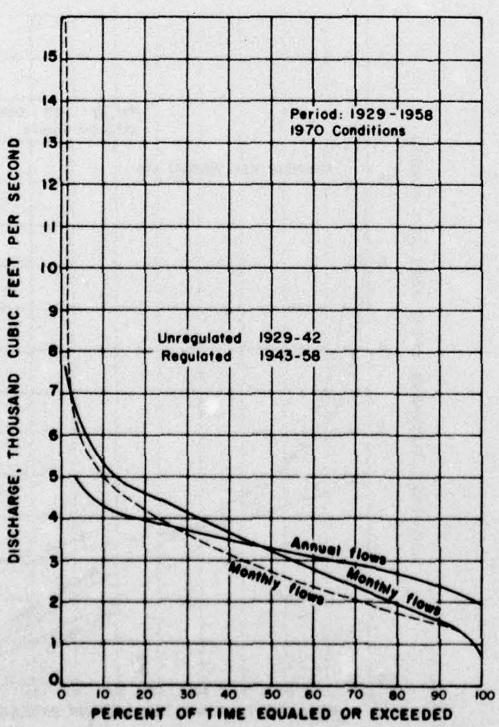


Figure 819 Duration curves, Puyallup River at Puyallup.

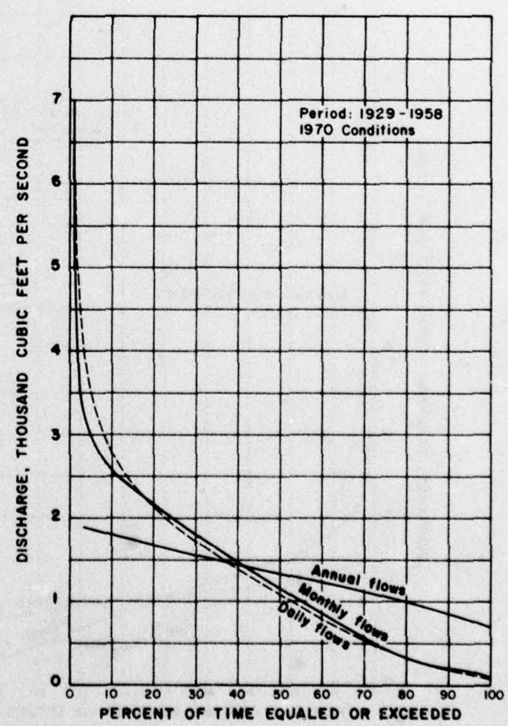


Figure 820 Duration curves, Green River near Auburn.

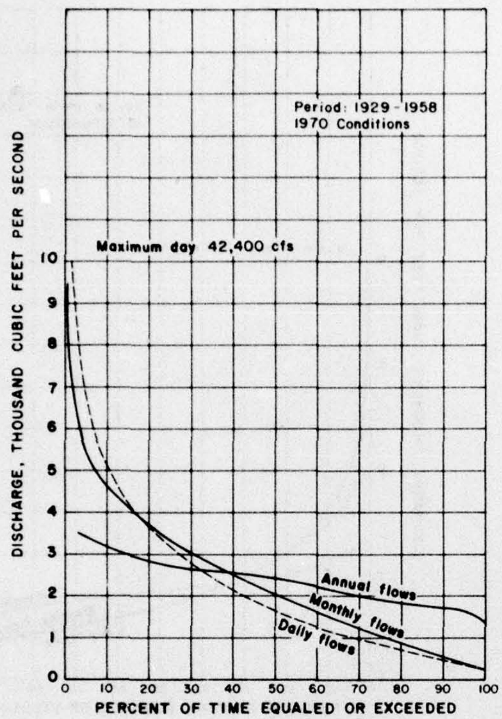


Figure 821 Duration curves, S. F. Skykomish River near Index.

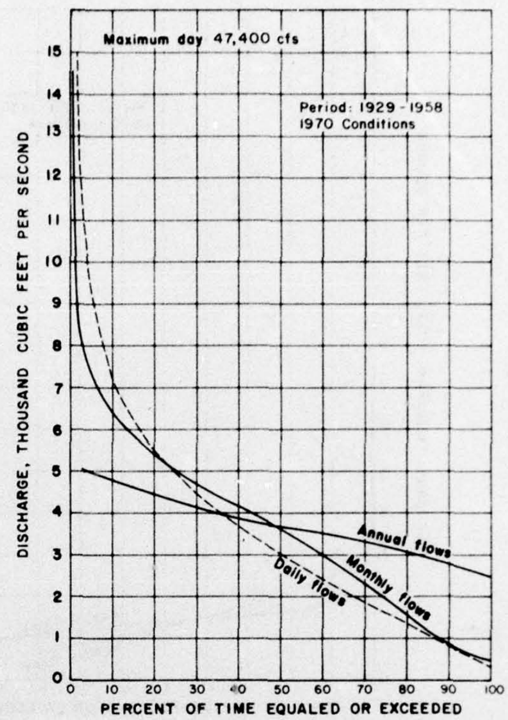


Figure 822 Duration curves, Snoqualmie River near Carnation.

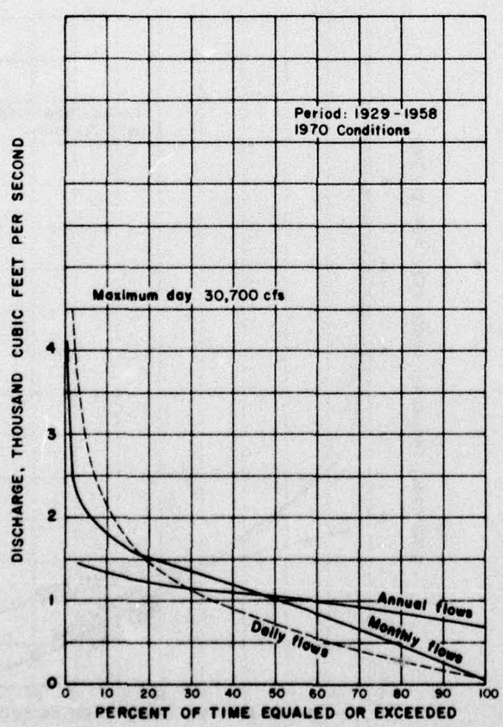


Figure 823 Duration curves, S. F. Stillaguamish River near Granite Falls.

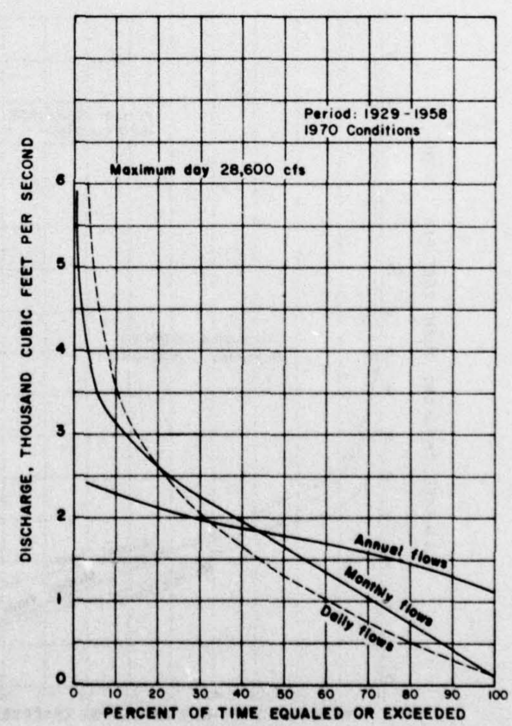


Figure 824 Duration curves, N. F. Stillaguamish River near Arlington.

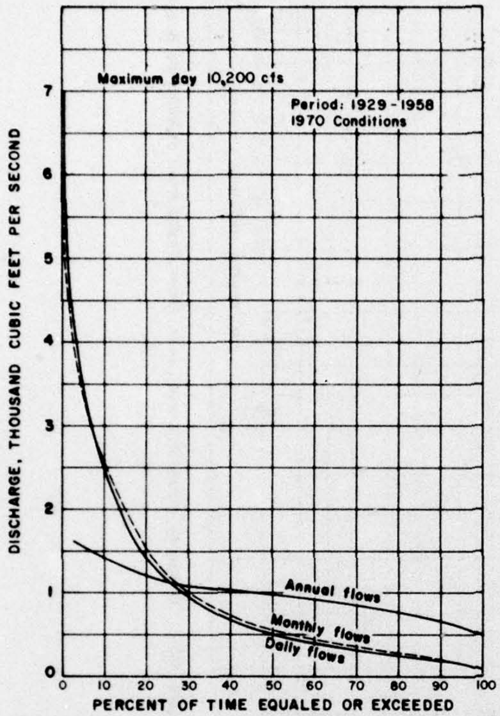


Figure 825 Duration curves, Skagit River near Hope, B.C.

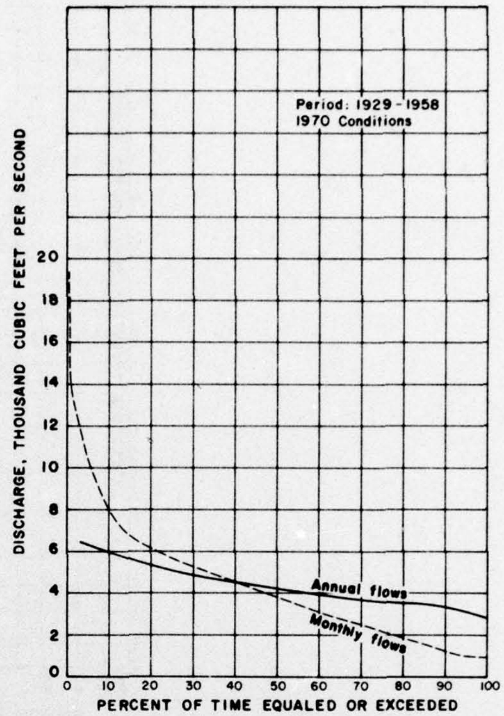


Figure 826 Duration curves, Skagit River at Newhalem.

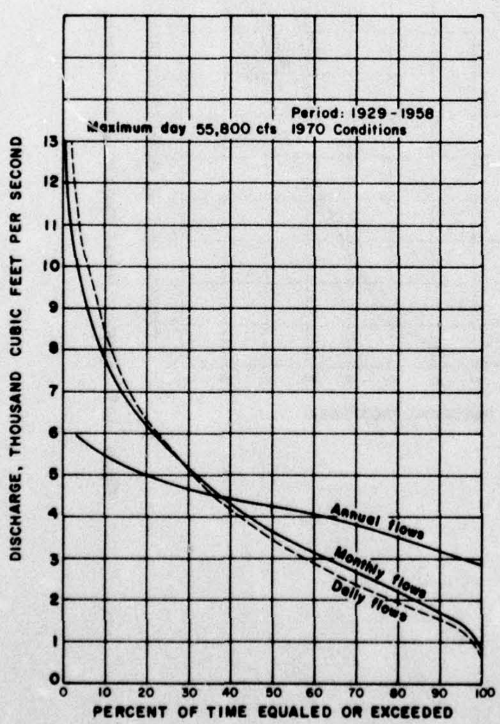


Figure 827 Duration curves, Sauk River near Sauk.

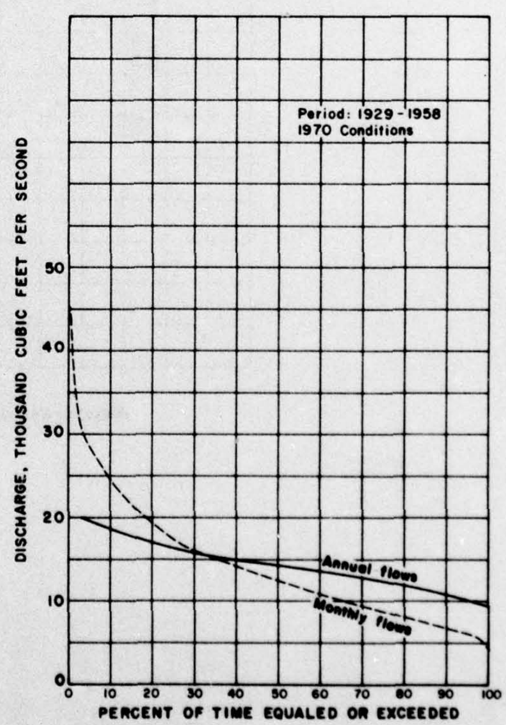


Figure 828 Duration curves, Skagit River near Concrete.

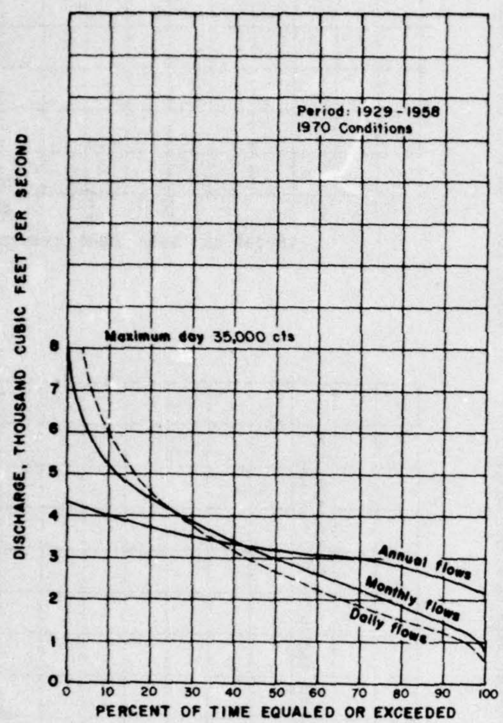


Figure 829 Duration curves, Nooksack River at Deming.

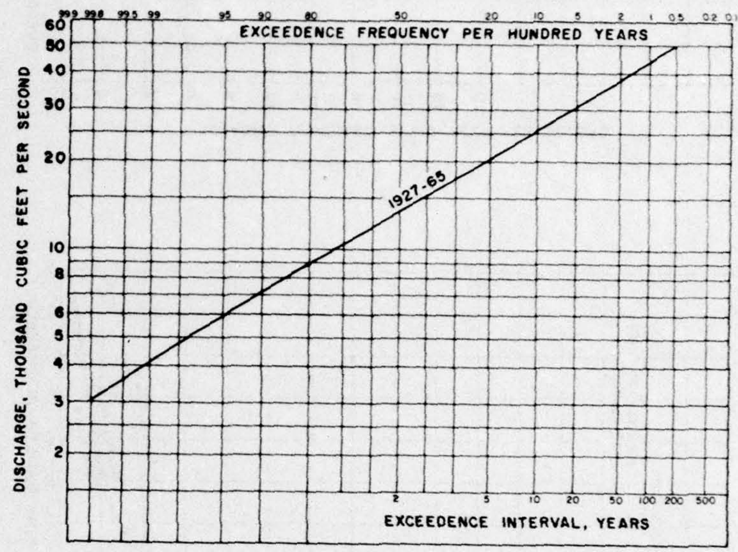


Figure 830 Frequency curve of annual peak flows, Elwha River at McDonald Bridge.

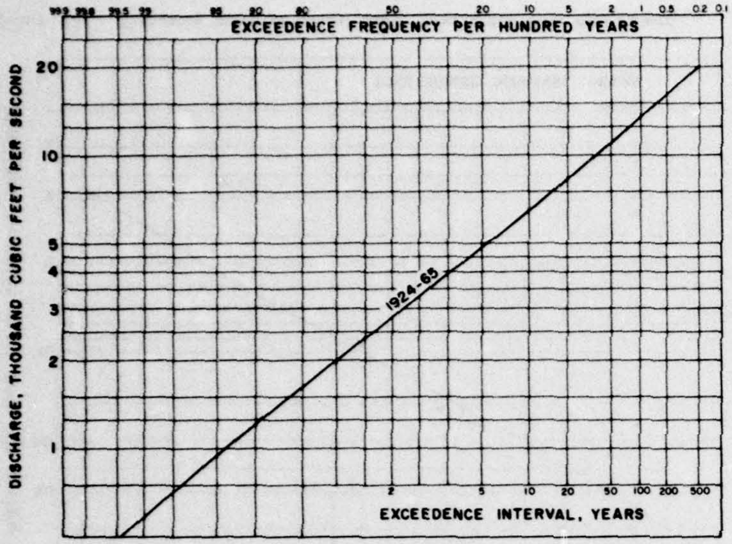


Figure 831 Frequency curve of annual peak flows, Dungness River near Sequim.

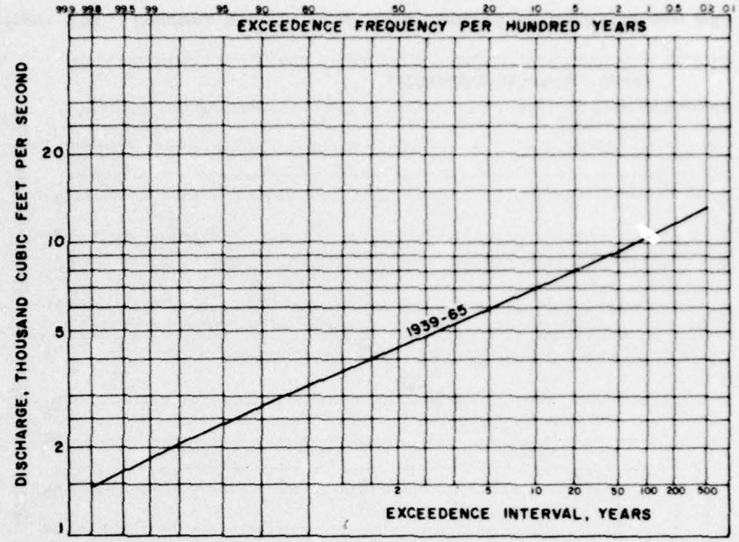


Figure 832 Frequency curve of annual peak flows, Duckabush River near Brinnon.

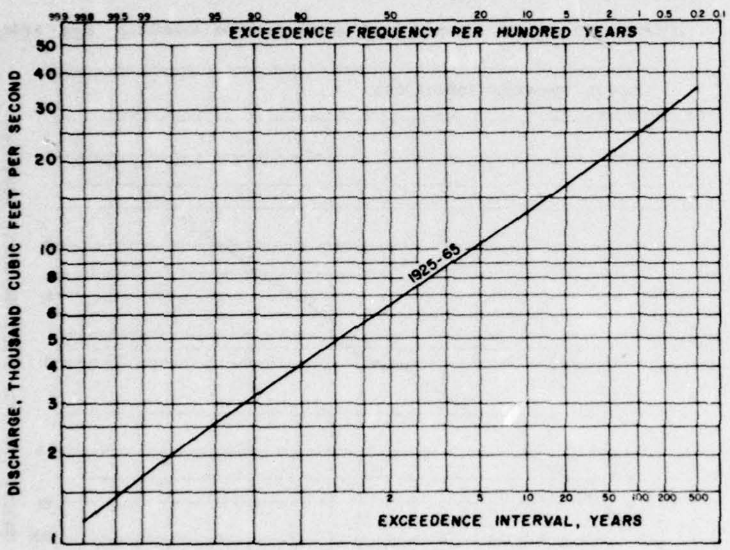


Figure 833 Frequency curve of annual peak flows, N.F. Skokomish River below Staircase Rapids.

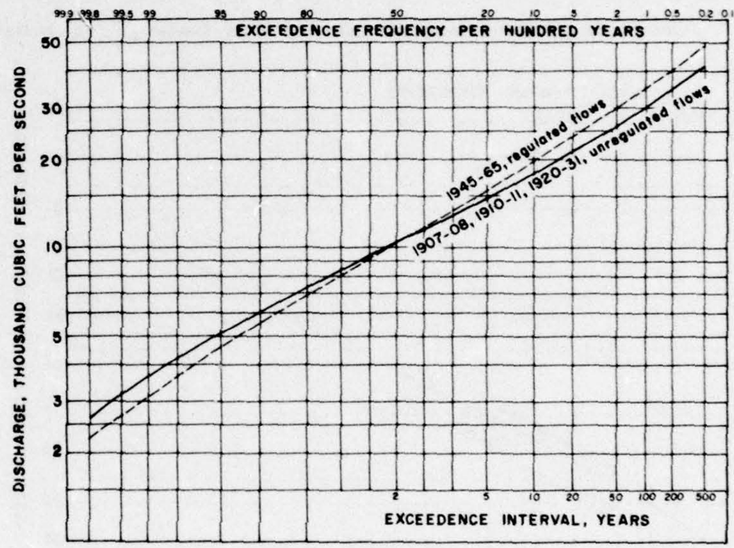


Figure 834 Frequency curve of annual peak flows, Nisqually River at LaGrande.

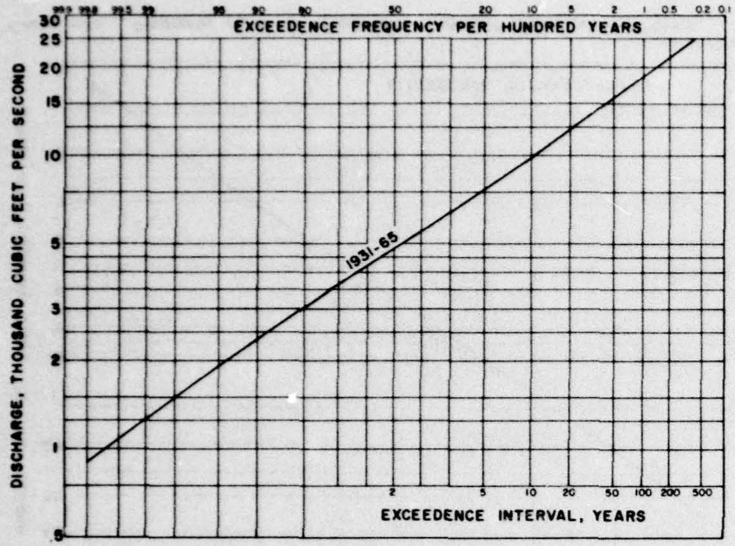


Figure 835 Frequency curve of annual peak flows, White River at Greenwater.

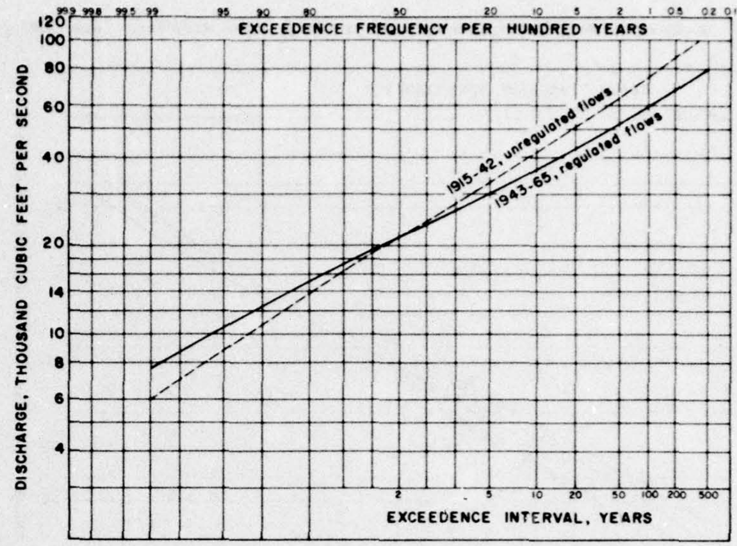


Figure 836 Frequency curve of annual peak flows, Puyallup River at Puyallup.

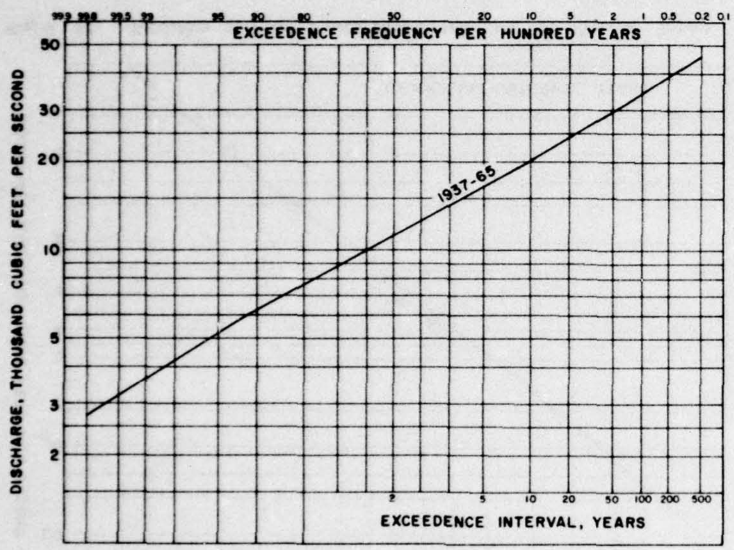


Figure 837 Frequency curve of annual peak flows, Green River near Auburn.

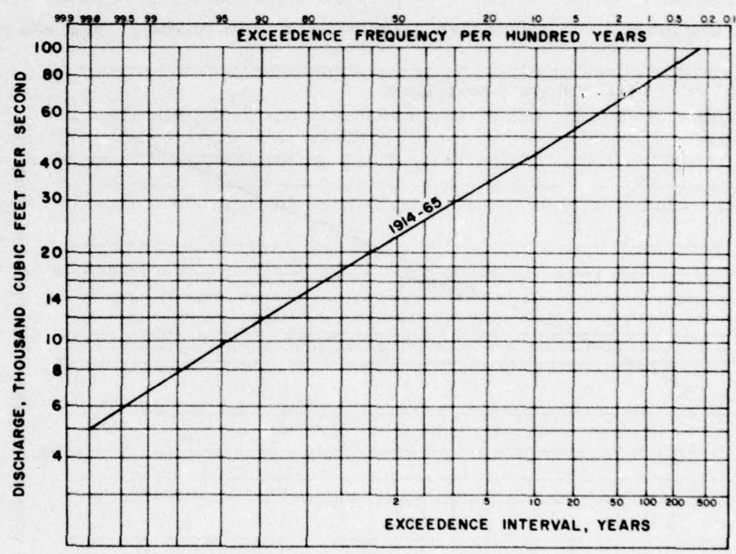


Figure 838 Frequency curve of annual peak flows, S.F. Skykomish River near Index.

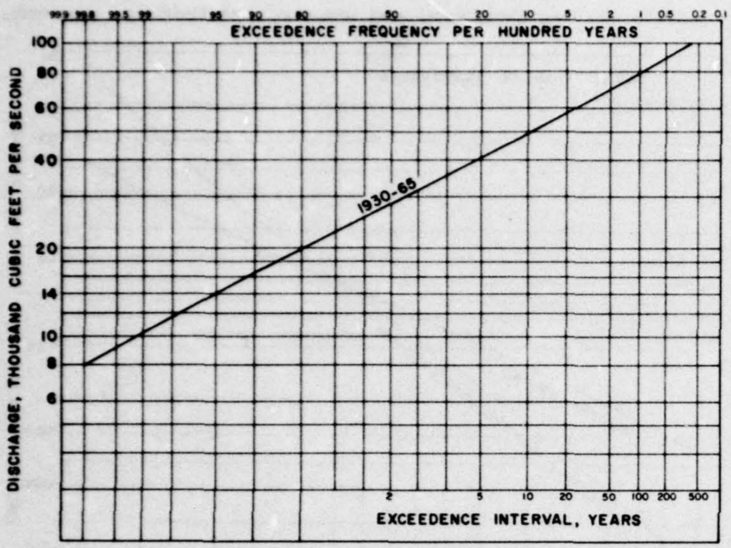


Figure 839 Frequency curve of annual peak flows, Snoqualmie River near Carnation.

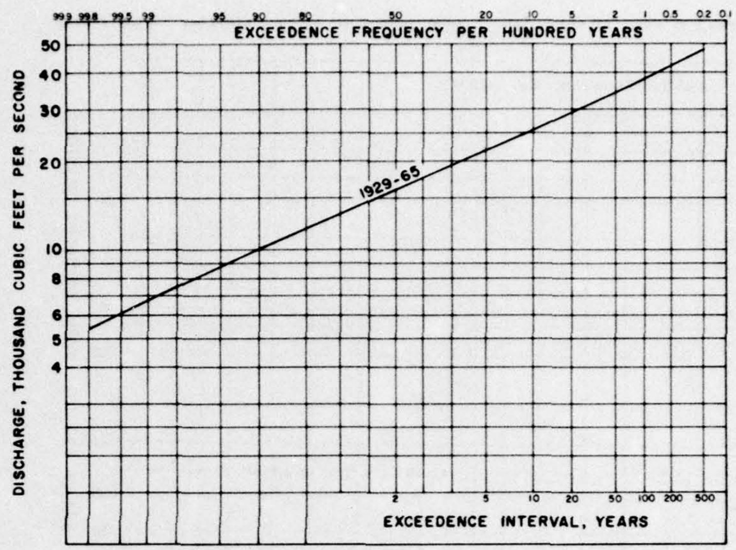


Figure 840 Frequency curve of annual peak flows, S.F. Stillaguamish River near Granite Falls.

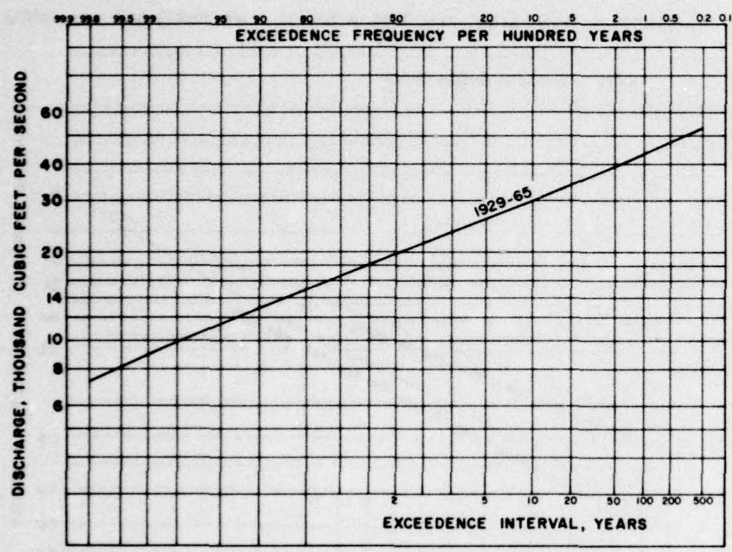


Figure 841 Frequency curve of annual peak flows, N.F. Stillaguamish River near Arlington.

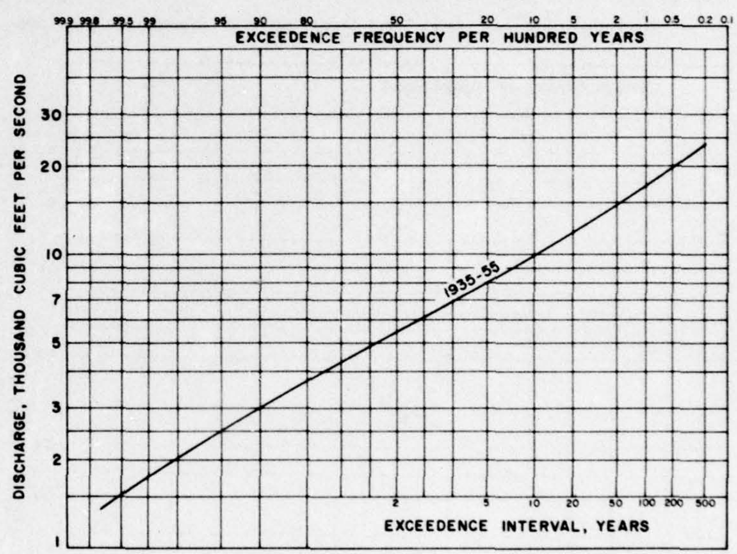


Figure 842 Frequency curve of annual peak flows, Skagit River near Hope, B. C.

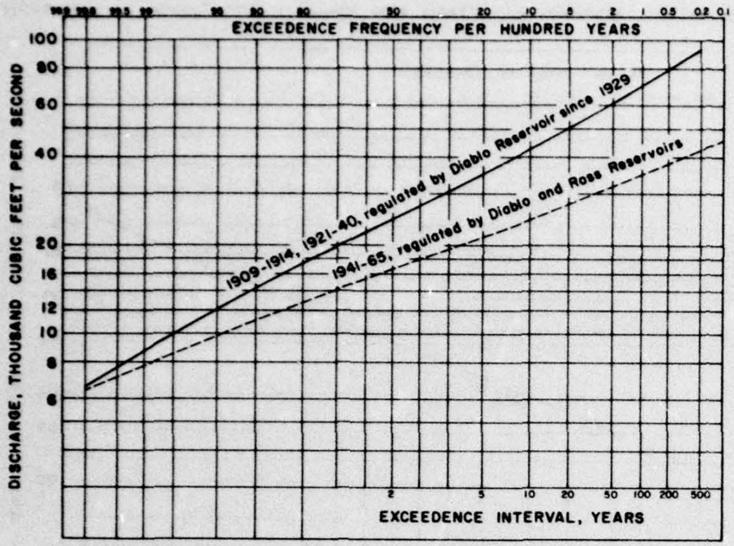


Figure 843 Frequency curve of annual peak flows, Skagit River at Newhalem.

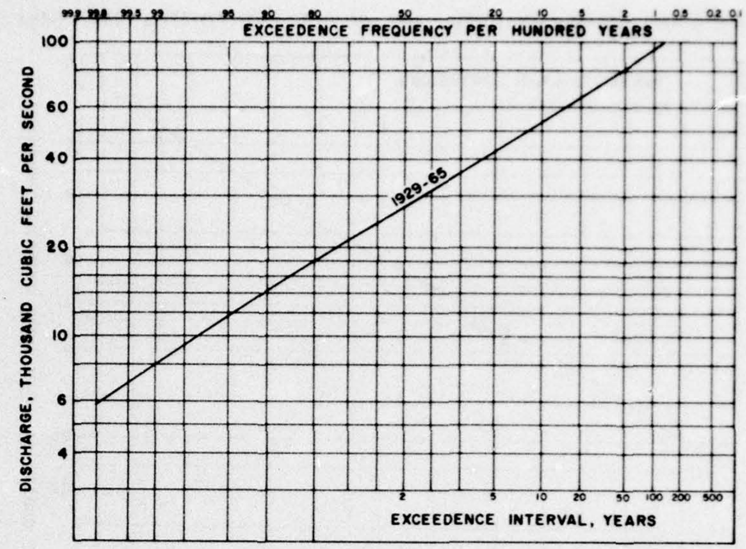


Figure 844 Frequency curve of annual peak flows, Sauk River near Sauk.

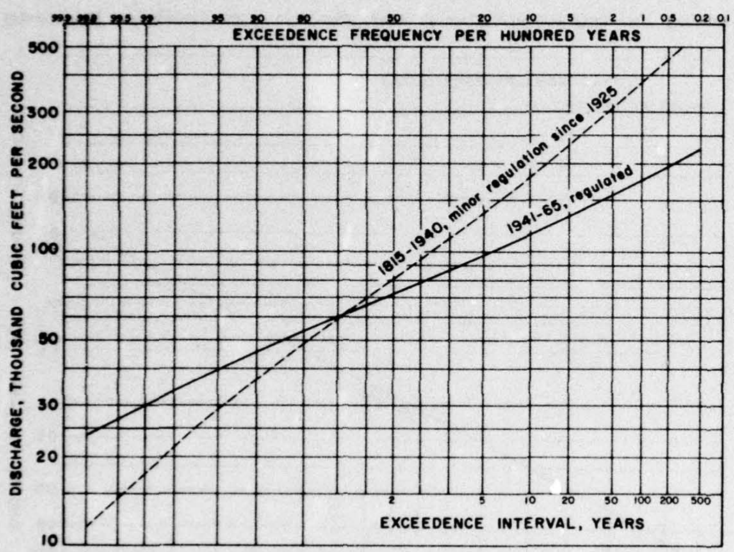


Figure 845 Frequency curve of annual peak flows, Skagit River near Concrete.

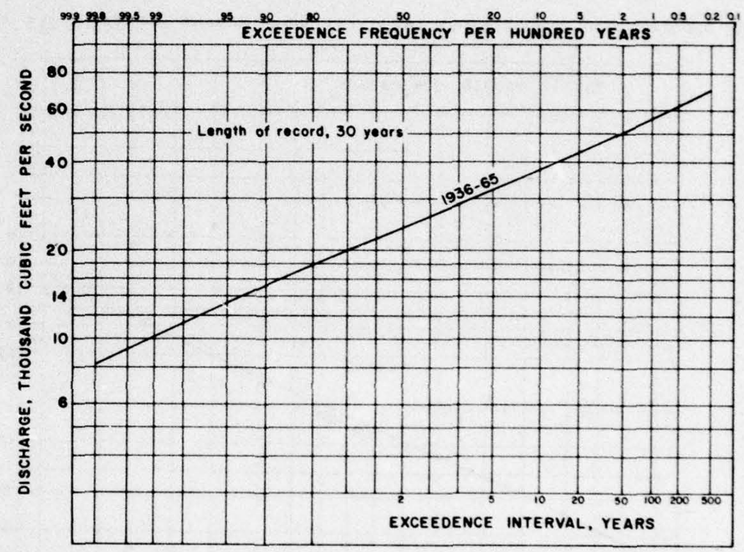


Figure 846 Frequency curve of annual peak flows, Nooksack River at Deming.

Table 453. Dependable Yield, Elwha River at McDonald Bridge near Port Angeles, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	859	59.0
2	1929-30	1,010	69.4
3	1942-44	1,058	72.6
4	1941-44	1,096	75.3
5	1941-45	1,133	77.9
6	1939-44	1,184	81.4
7	1939-45	1,197	82.2
8	1937-44	1,228	84.3
9	1936-44	1,228	84.3
10	1936-45	1,233	84.7
30	1929-58	1,456	100.0

Table 454. Dependable Yield, Dungeness River near Sequim, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	199	53.7
2	1929-30	248	66.9
3	1929-31	265	71.5
4	1942-45	288	77.7
5	1941-45	295	79.5
6	1941-46	304	82.0
7	1939-45	306	82.5
8	1939-46	311	83.9
9	1939-47	314	84.7
10	1936-45	315	84.9
30	1929-58	371	100.0

Table 455. Dependable Yield, Duckabush River near Brinnon, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	217	55.4
2	1929-30	238	60.7
3	1929-31	265	67.6
4	1929-32	299	76.3
5	1929-33	325	82.9
6	1939-44	344	87.8
7	1939-45	349	89.1
8	1937-44	355	90.6
9	1936-44	352	89.8
10	1936-45	356	90.8
30	1929-58	392	100.0

Table 456. Dependable Yield, N. F. Skokomish River Below Staircase Rapids near Hoodsport, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	256	52.6
2	1929-30	283	58.2
3	1929-31	319	65.6
4	1929-32	364	74.8
5	1929-33	396	81.4
6	1939-44	417	85.6
7	1939-45	425	87.3
8	1937-44	428	88.0
9	1936-44	428	88.0
10	1936-45	432	88.8
30	1929-58	487	100.0

Table 457. Dependable Yield, Nisqually River at La Grande, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	803	57.9
2	1944-45	934	67.4
3	1929-31	1,008	72.8
4	1941-44	1,061	76.6
5	1941-45	1,044	75.4
6	1940-45	1,066	77.0
7	1939-45	1,080	78.0
8	1938-45	1,127	81.4
9	1937-45	1,136	82.0
10	1936-45	1,150	83.1
30	1929-58	1,385	100.0

Table 458. Dependable Yield, White River at Greenwater, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	558	66.7
2	1929-30	578	69.1
3	1929-31	591	70.6
4	1929-32	659	78.7
5	1940-44	672	80.3
6	1939-44	678	81.0
7	1939-45	686	82.0
8	1937-44	714	85.2
9	1936-44	712	85.1
10	1936-45	715	85.4
30	1929-58	837	100.0

Table 459. Dependable Yield, Puyallup River at Puyallup, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	2,087	63.4
2	1930-31	2,260	68.7
3	1929-31	2,363	71.8
4	1941-44	2,604	79.2
5	1940-44	2,627	79.9
6	1940-45	2,669	81.1
7	1939-45	2,725	82.8
8	1937-44	2,824	85.8
9	1937-45	2,823	85.8
10	1936-45	2,865	87.0
30	1929-58	3,292	100.0

Table 460. Dependable Yield, Green River near Auburn, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	662	50.8
2	1940-41	817	62.6
3	1929-31	854	65.5
4	1941-44	982	75.3
5	1940-44	980	75.2
6	1939-44	1,013	77.7
7	1939-45	1,052	80.6
8	1937-44	1,076	82.5
9	1936-44	1,091	83.7
10	1936-45	1,111	85.2
30	1929-58	1,306	100.0

Table 461. Dependable Yield, S. F. Skykomish River near Index, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	1,352	56.7
2	1940-41	1,610	67.5
3	1929-31	1,703	71.4
4	1941-44	1,885	79.0
5	1940-44	1,881	78.9
6	1940-45	1,919	80.5
7	1939-45	1,988	83.4
8	1937-44	2,002	83.9
9	1937-45	2,014	84.5
10	1936-45	2,027	85.0
30	1929-58	2,385	100.0

Table 462. Dependable Yield, Snoqualmie River near Carnation, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	2,314	62.3
2	1929-30	2,645	71.2
3	1929-31	2,760	74.3
4	1941-44	3,010	81.0
5	1940-44	3,027	81.5
6	1940-45	3,114	83.8
7	1938-44	3,187	85.8
8	1937-44	3,176	85.5
9	1936-44	3,206	86.3
10	1936-45	3,241	87.2
30	1929-58	3,714	100.0

Table 463. Dependable Yield, S. F. Stillaguamish River near Granite Falls, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	702	67.2
2	1929-30	712	68.1
3	1929-31	796	76.2
4	1941-44	818	78.2
5	1940-44	827	79.1
6	1940-45	853	81.6
7	1938-44	882	84.3
8	1937-44	879	84.1
9	1936-44	885	84.6
10	1936-45	895	85.6
30	1929-58	1,045	100.0

Table 464. Dependable Yield, N. F. Stillaguamish River near Arlington, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	1,120	63.3
2	1929-30	1,175	66.9
3	1929-31	1,333	75.4
4	1941-44	1,435	81.1
5	1940-44	1,462	82.6
6	1940-45	1,489	84.1
7	1936-42	1,524	86.1
8	1937-44	1,519	85.8
9	1936-44	1,517	85.7
10	1936-45	1,518	86.3
30	1929-58	1,770	100.0

Table 465. Dependable Yield, Skagit River near Hope, B. C.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	488	50.0
2	1940-41	578	59.2
3	1940-42	645	66.0
4	1939-42	698	71.5
5	1940-44	693	71.0
6	1940-45	694	71.0
7	1939-45	717	73.4
8	1938-45	749	76.7
9	1937-45	760	77.8
10	1936-45	760	77.8
30	1929-58	977	100.0

Table 466. Dependable Yield, Skagit River at Newhalem, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	2,717	62.4
2	1944-45	3,165	72.7
3	1929-31	3,344	76.9
4	1941-44	3,444	79.2
5	1940-44	3,467	79.7
6	1940-45	3,491	80.2
7	1939-45	3,541	81.4
8	1938-45	3,663	84.2
9	1937-45	3,658	84.1
10	1936-45	3,660	84.1
30	1929-58	4,351	100.0

Table 467. Dependable Yield, Sauk River at Sauk, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	2,887	68.1
2	1929-30	3,060	72.2
3	1929-31	3,240	76.4
4	1941-44	3,402	80.3
5	1940-44	3,441	81.2
6	1940-45	3,486	82.2
7	1939-45	3,589	84.7
8	1937-44	3,640	85.9
9	1937-45	3,648	86.1
10	1936-45	3,666	86.5
30	1929-58	4,241	100.0

Table 468. Dependable Yield, Skagit River near Concrete, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	9,507	66.9
2	1929-30	10,544	74.1
3	1929-31	11,084	77.9
4	1941-44	11,488	80.7
5	1941-45	11,679	82.0
6	1940-45	11,796	82.9
7	1939-45	12,060	84.7
8	1937-44	12,272	86.2
9	1937-45	12,291	86.3
10	1936-45	12,328	86.7
30	1929-58	14,224	100.0

Table 469. Dependable Yield, Nooksack River at Deming, Wash.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	2,220	69.0
2	1929-30	2,305	71.7
3	1929-31	2,550	79.3
4	1941-44	2,602	80.8
5	1941-45	2,667	82.9
6	1940-45	2,727	84.7
7	1939-45	2,792	86.7
8	1937-44	2,825	87.8
9	1937-45	2,836	88.1
10	1936-45	2,856	88.8
30	1929-58	3,217	100.0

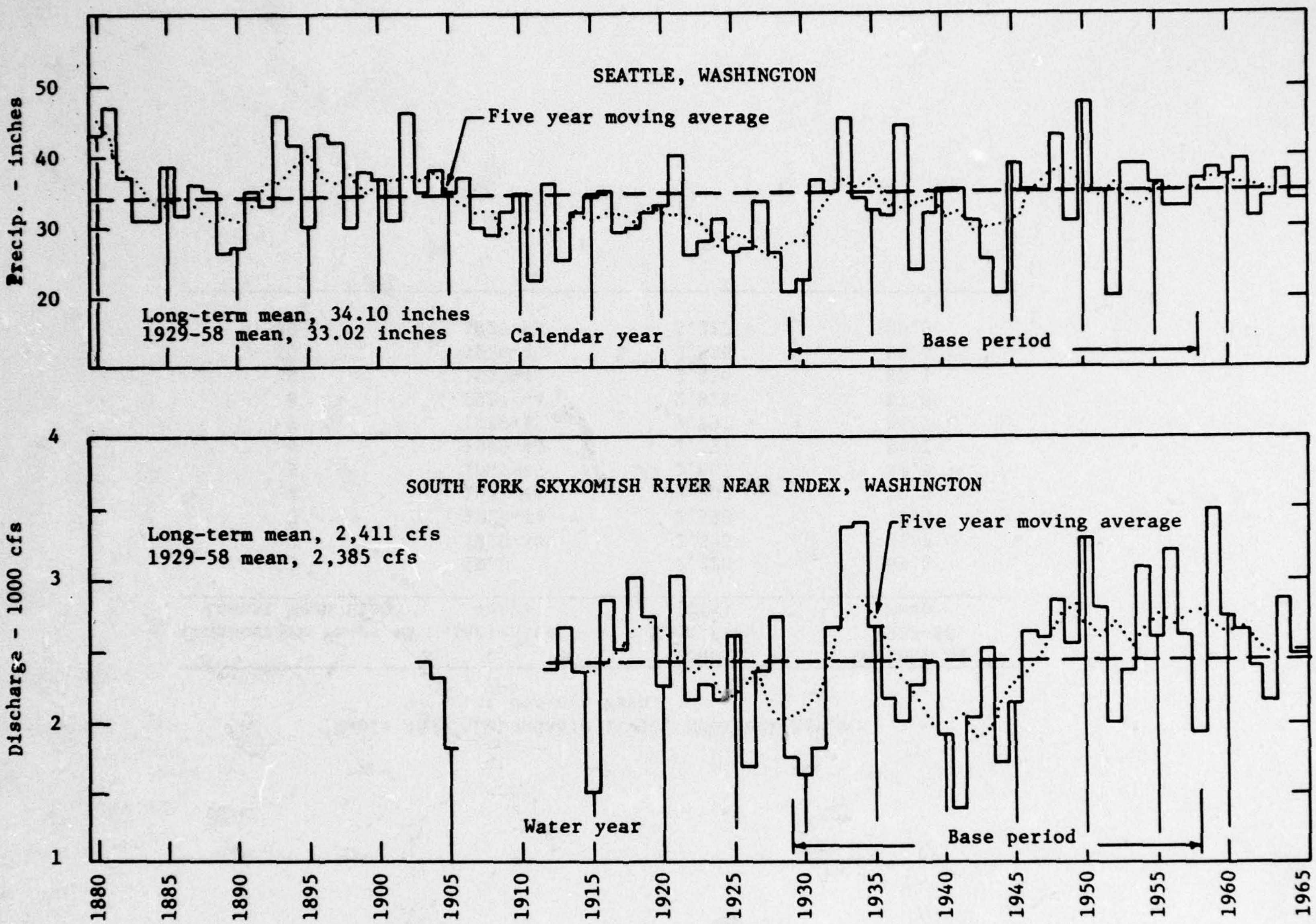


FIGURE 847. Long-term variation in precipitation and streamflow.

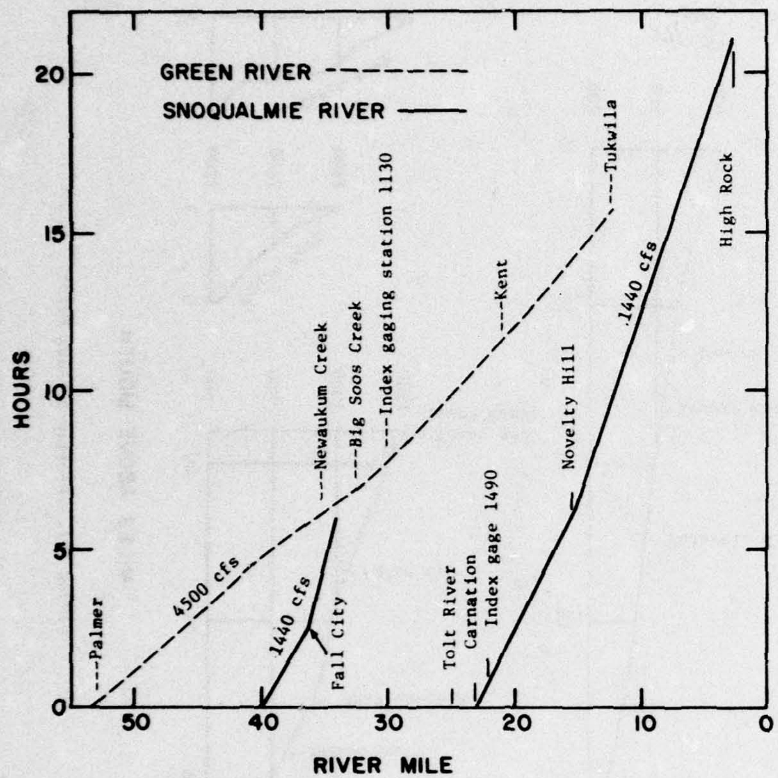


FIGURE 848. Time of travel, Green and Snoqualmie Rivers, for selected discharges at index stations.

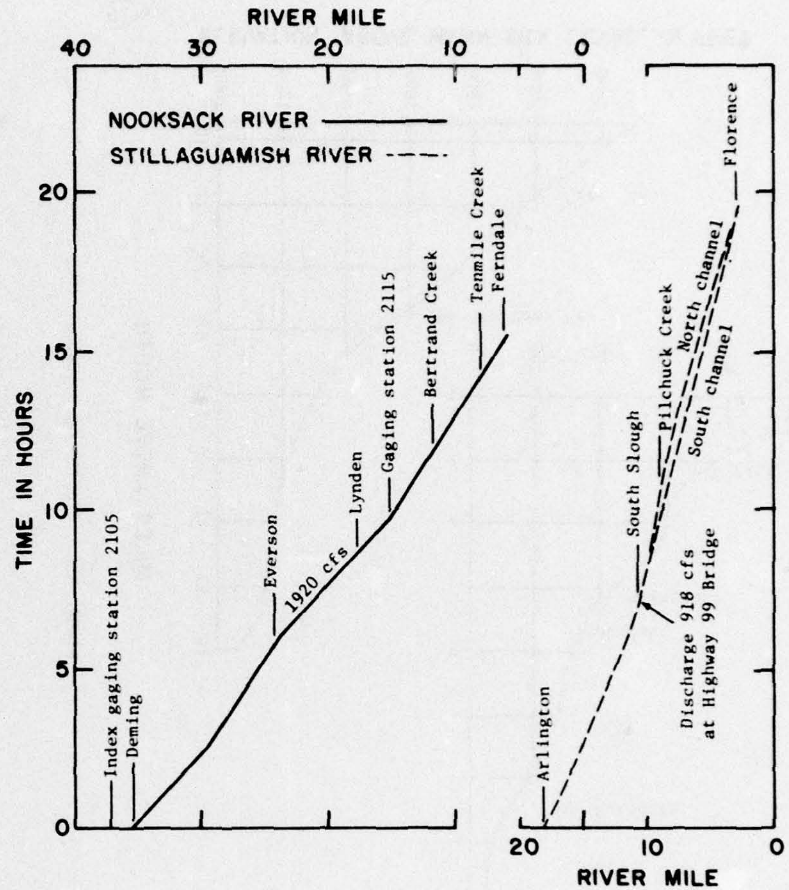


FIGURE 849. Time of travel, Stillaguamish and Nooksack Rivers, for selected discharges at index gaging stations or points.

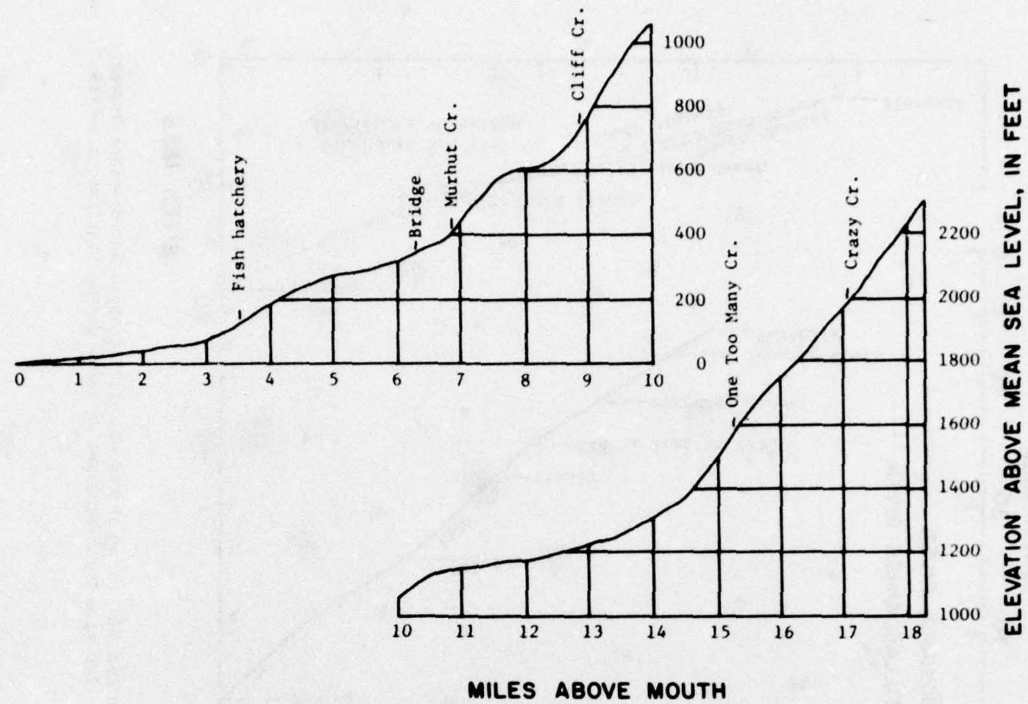


FIGURE 850. Profile of Duckabush River.

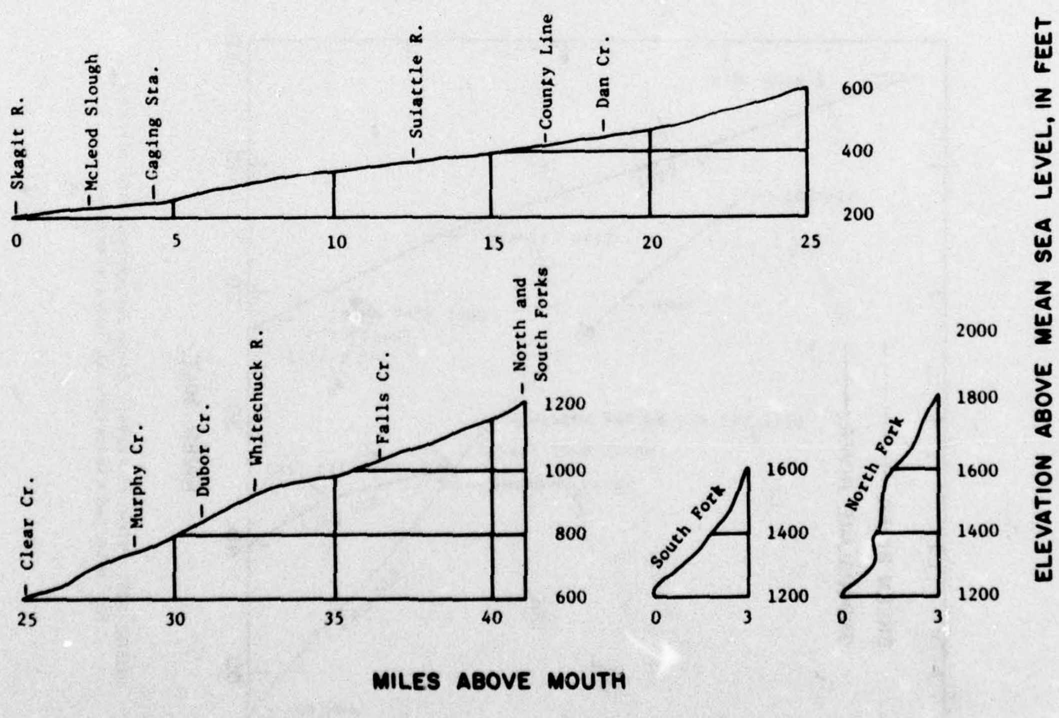


FIGURE 851.--Profile of Sauk River.

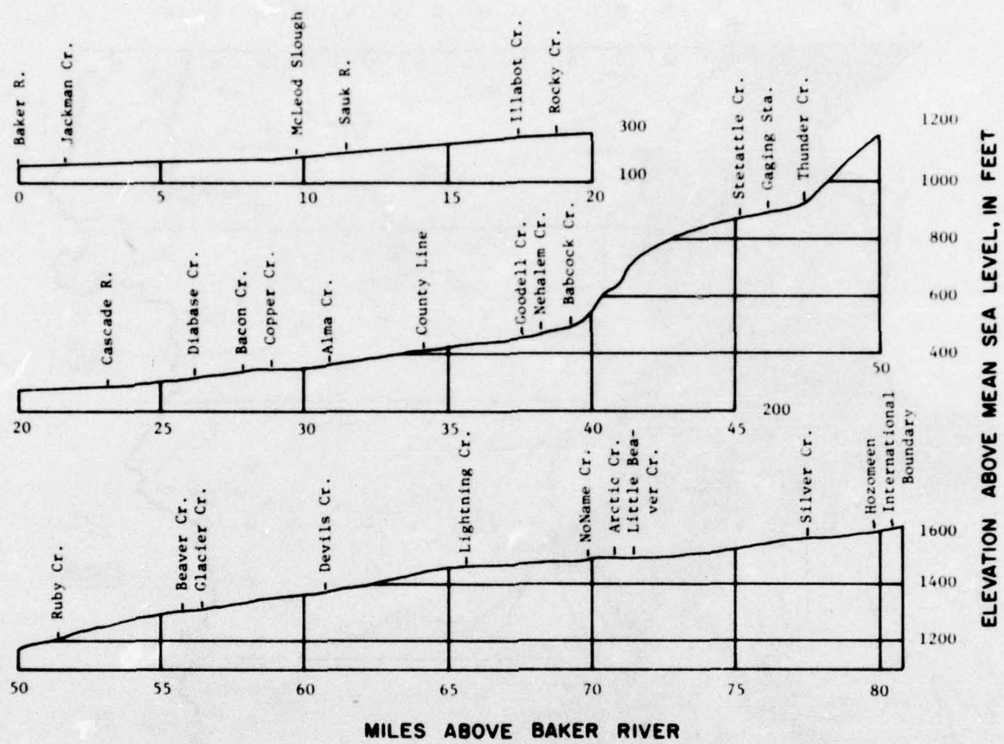


FIGURE 852. Profile of Skagit River above Baker River.

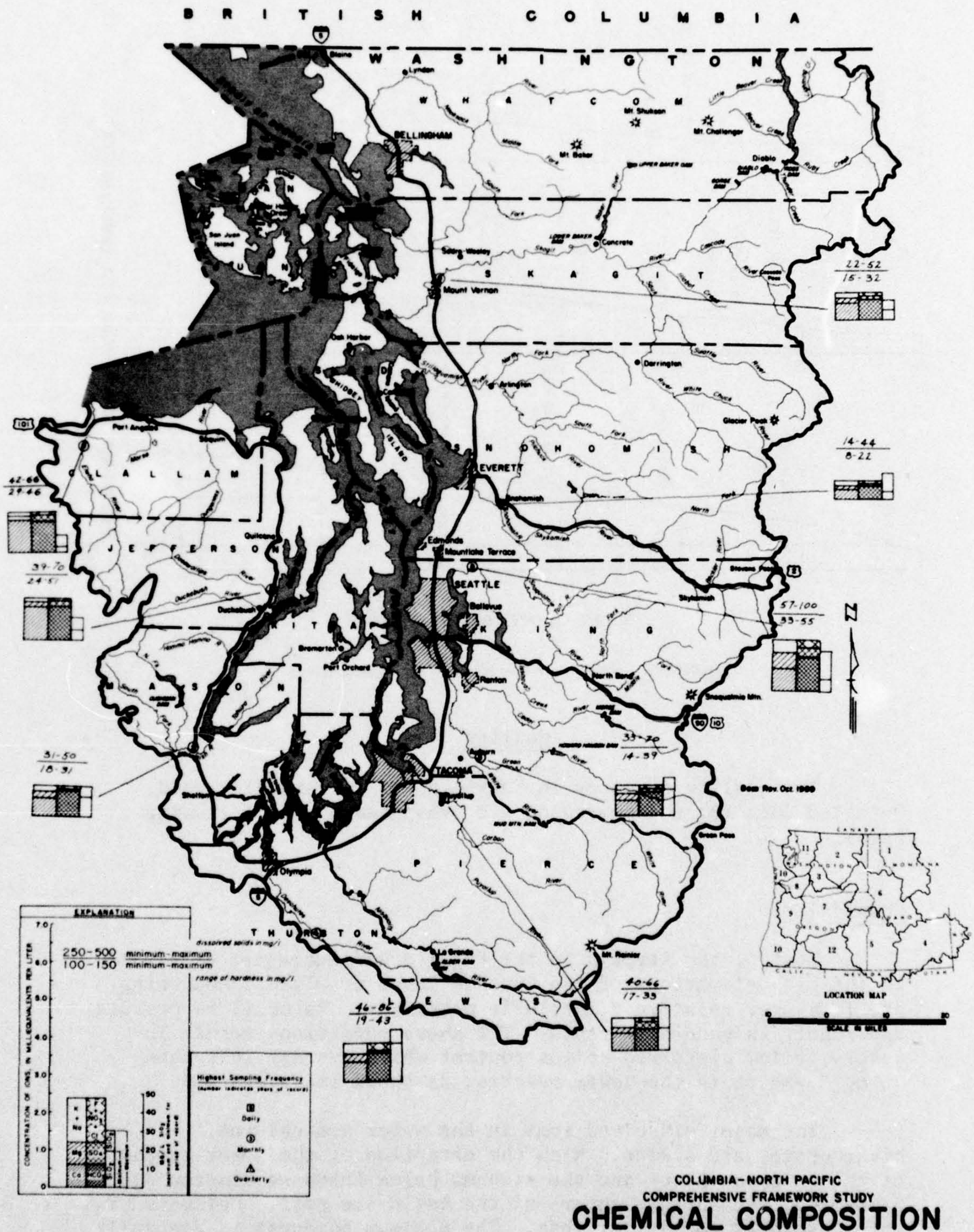
Quality

The quality of water in Subregion 11 is generally good. Detailed data for the subregion are presented on the following pages.

Chemical

Most of the streams in the Puget Sound Subregion originate in the high elevations of the Cascade Range or Olympic Mountains and flow over relatively insoluble materials. Rainfall is profuse and runoff is generally rapid. The above conditions result in waters of low dissolved-solids content which average less than 75 mg/l except in the lower reaches, as shown in figure 853.

The major dissolved ions in the water are calcium, bicarbonate, and silica. With the exception of the lower reaches of the Duwamish River and the streams below Lakes Washington and Sammamish, the surface waters of the basin are soft. Hardness of water averages 40 mg/l or less. The maximum hardness is generally less than 60 mg/l.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

PUGET SOUND SUBREGION II

1968

FIGURE 853

There is some downstream increase in mineralization of the surface water in the basin. The increase is significant only in the lower reaches of the Duwamish River and in streams in the Seattle-Tacoma area. Data from the Duwamish River at Tukwila indicate considerable variation in the chemical quality of the river in this reach. The major causes of this variation are the influence of salt water from Puget Sound and the discharge of sewage and industrial wastes.

During low-flow periods the mineral content of the surface waters usually increases because the more mineralized ground water makes up a larger percentage of the total flow. During high-flow periods dilute surface runoff is the larger contributor to streamflow; consequently, mineral content is generally less than 50 mg/l. In dilute surface waters the difference in mineral content between high- and low-flow periods can be fairly large. The minimum dissolved-solids content of the major streams in the Puget Sound Subregion averages about 60 percent of the maximum. This difference is not of great significance to the water user because the maximum dissolved-solids content is low, usually less than 100 mg/l.

In general, the surface waters of the Puget Sound Subregion are suitable for most uses. Industrial users who require very low silica content would have to treat most water in the basin. Pollution from domestic and industrial sources in the Seattle-Tacoma area has deteriorated the quality of surface waters and rendered them less suitable for many uses without considerable treatment.

Biological-Biochemical

Dissolved-oxygen concentration levels are at or near the saturation level (80 percent saturation) in nearly all fresh and marine waters of Puget Sound. A few bays and lower river reaches are subjected to the discharge of large quantities of partially treated or untreated wastes, with depressed oxygen levels being one of the resulting effects. These areas are located primarily on the lowlands along eastern Puget Sound, where a sizable megalopolis is in the first evolving stages.

The estuarial reach of the Duwamish River has low dissolved-oxygen levels during the late summer and early fall. Bottom dissolved oxygen concentrations have ranged between 3 and 4 mg/l, with the minimum dropping below 2 mg/l. Surface concentrations during this period range between 5 and 6 mg/l. During this low-flow period, tides are the predominate factor affecting changes in dissolved oxygen. Minor increases in fresh-water flows are of

little value in raising oxygen levels through the depressed reach. In South Tacoma, Flett Creek has exhibited dissolved-oxygen levels as low as 4.5 mg/l during the fall.

Bottom dissolved-oxygen concentrations approaching 0.0 mg/l in Lake Union result from solids deposited during past heavy industrial waste loadings.

Bellingham, Everett, and Port Angeles harbors periodically exhibit low concentrations of dissolved oxygen. All receive massive loadings of industrial wastes as well as municipal wastes. Bellingham harbor sometimes has dissolved-oxygen levels as low as 4 or 5 mg/l. Zero dissolved oxygen occasionally occurs in some places in Everett harbor. Port Angeles harbor surface waters periodically have dissolved-oxygen levels of less than 5 mg/l.

Bacteriological quality, although variable, generally reflects the density of urban or agricultural buildup. High densities of total coliform organisms occur in the same areas as low dissolved oxygen, as well as in a few other areas. Outside the developed lowlands along eastern Puget Sound and at Port Angeles harbor, the streams and the sound receive little waste and are mostly of excellent bacteriological quality.

Table 470 - Coliform Organisms Densities

	Most Probable Number/100 ml			
Location	Min.	Max.	Median	No.
Nooksack River near Ferndale	36	24,000	930	53
Skagit River near Mt. Vernon	0	24,000	430	80
Snohomish River at Snohomish	23	24,000	930	52
Sammamish River at Bothell	91	11,000	930	51
Issaquah Creek near Issaquah	1,500	24,000	11,000	5
Duwamish River at Tukwila	230	240,000	4,600	42
Boise Creek near Buckley	1,500	240,000	6,100	8
Puyallup River near Puyallup	0	24,000	4,600	31
Flett Creek near Tacoma	91	24,000	2,400	36
Leach Creek near Steilacoom	0	11,000	430	36

As indicated in table 470, high coliform densities periodically occur in the Nooksack River near Ferndale just upstream from Bellingham harbor; Skagit River near Mount Vernon; Snohomish River at Snohomish, near Everett; Sammamish River, Issaquah Creek, and Duwamish River, all near Seattle; Boise Creek near Buckley; and Puyallup River and Flett and Leach Creeks near Tacoma. High densities also occur in Port Angeles harbor. Most high coliform densities result from loadings by untreated or inadequately treated municipal wastes. In some rural areas, occasional high-coliform densities occur from runoff from dairy farms.

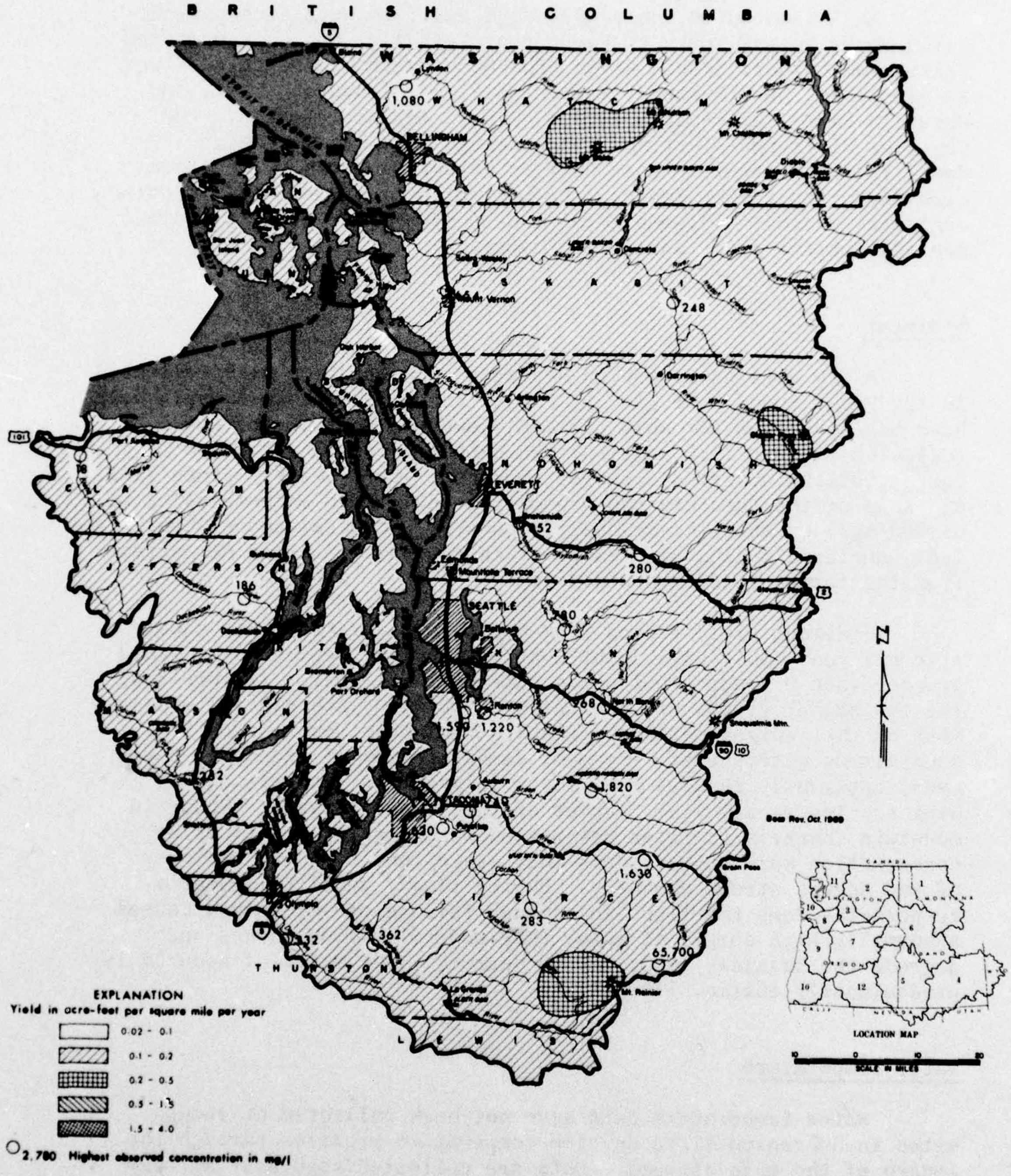
Sediment

A few data on suspended-sediment concentration were collected in the Puget Sound Subregion in 1911. Since 1950, considerable data have been obtained for many streams; however, most of the data collected between 1950 and 1961 are unpublished. The highest concentrations observed occurred in recent years, mostly since 1962, and some of the data are shown on figure 854. The extreme value of 65,700 mg/l on White River near Greenwater was observed on October 2, 1964, during a medium high-water discharge about 3 miles downstream from the terminus of Emmons Glacier.

Sediment yield ranges from 0.1 to 0.5 acre-feet per square mile per year (30); only about 3 percent of the region has a yield greater than 0.2 acre-foot per square mile per year. (figure 854) The few higher yields are generally associated with glacial erosion. Most of the sediment probably results from sheet erosion on the mountainous watersheds. The most damaging type of sediment, however, apparently results from scour in mountain channels and in bank erosion in alluvial reaches of the larger streams. Scour in mountain channels is often associated with logging practices or construction work near streams that leave debris in the vicinity of and across stream channels. During flood runoff this debris temporarily dams the flow, and sudden failure of such a dam causes abnormally high surges of water that undermine side slopes and degrade the channel, sometimes to bedrock. The material scoured is predominantly coarse. (30-AV3)

Water Temperature

Water-temperature data have not been collected at enough sites in Subregion 11 to develop temperature profiles through the length of the main streams. Data are collected regularly at only one of the stations selected for detailed analysis, Green River near Auburn. Temperature data for Green River



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

PUGET SOUND SUBREGION II

1968

FIGURE 854

and for two other streams in the subregion, South Fork Skokomish River near Potlatch and Skagit River near Mount Vernon, where data have been collected for several years, are shown on figure 855. The longer the record the greater the spread between maximum and minimum water temperatures; however, the means shown are fairly representative of the long-term means. The monthly mean water temperatures for 1963 also are fairly representative of the long-term means.

During the 14 years to 1966 that water temperatures have been obtained on Green River at Auburn, the mean for July ranged between 58° and 62°F. The maximum July water temperatures ranged from 62° to 75°F., the minimum from 53° to 56°F.

GROUND WATER

The alluvial and glaciofluvial deposits that blanket the Puget Sound lowland and cover the floors of valleys in the foothills constitute the most important aquifers in the Puget Sound area. Moderate to large yields of water of good to excellent quality are obtained at many places, and the deposits are capable of sustaining a much larger development. In this report those deposits are considered to form a single aquifer unit. Other aquifer units are important as sources of supply locally, or are important in the streamflow regimen.

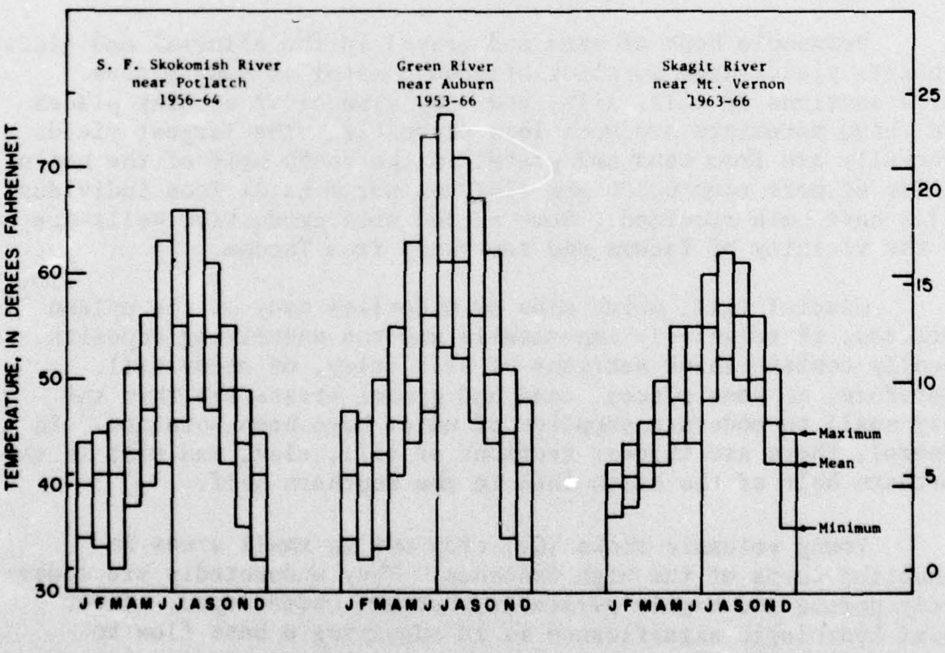


FIGURE 855. Monthly water temperatures for selected stations. Top, middle and bottom bars represent maximum, mean and minimum, respectively.

There are a number of published reports describing aquifers and ground-water occurrence in various parts of the Puget Sound lowland in some detail (36, 39, 67, 90, 96, 102, 104, 105, 139, 140, 189, 197, 198).

Aquifer Units and Their Hydrologic Characteristics

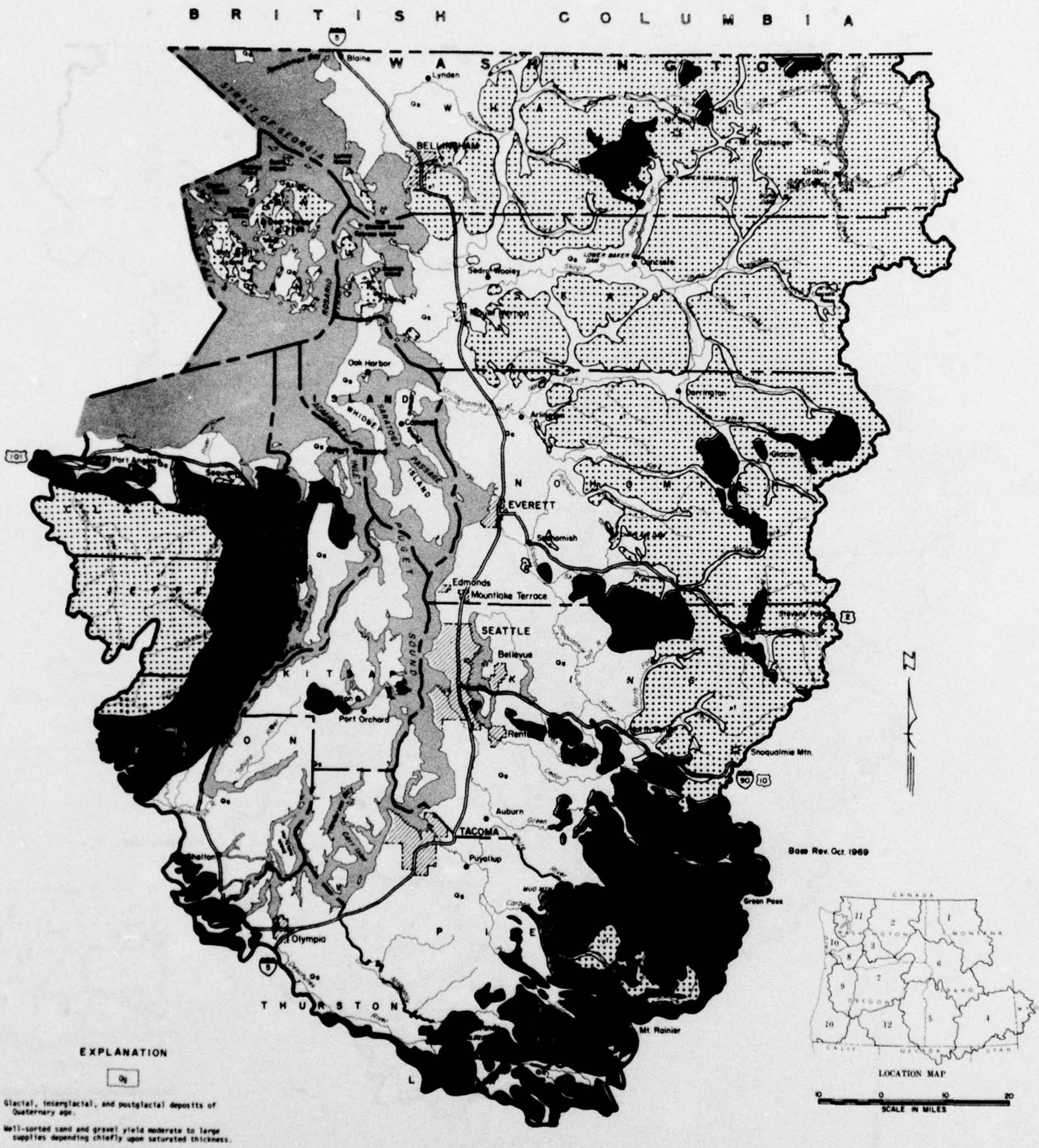
Five aquifer units have been delineated in Subregion 11 but only one (Qg) is capable of yielding large supplies of ground water. Areal distribution of the aquifer units is shown on the map, figure 856, which is based on the Geologic Map of Washington (54).

Geologically young alluvial and glacial deposits (Qg) form a deep fill throughout most of the lowland. These deposits include more than a dozen formations and aquifers that have been described in the various reports referenced above. They can be separated into four categories: (1) alluvium (post glacial); (2) recessional outwash, associated with the most recent (Fraser) glaciation; (3) till, associated with the Fraser glaciation; and (4) glacial and interglacial sediments deposited prior to the till. Category (4) includes 90 percent or more of the basin fill at most places; categories (1) to (3) generally form only the uppermost 50 to 100 feet. At many places wells may tap any or all of these units, therefore it did not seem practicable to separate the four categories in this report. The entire basin fill of Quaternary age is considered to be a single aquifer unit.

Permeable beds of sand and gravel in the alluvial and glacial deposits yield large supplies of ground water at many places. Thick sections of till, silt, and clay also occur at many places and these materials are much less permeable. The largest yields generally are from sand and gravel in the south half of the basin. Yields of more than 6,000 gpm (gallons per minute) from individual wells have been recorded. Some of the most productive wells are in the vicinity of Tacoma and southward from Tacoma.

Glacial till, which caps or underlies many of the upland surfaces, is relatively impermeable and the underlying deposits locally contain thick sections of silt, clay, or older till. Therefore, at some places, sand and gravel strata are thin and only small to moderate supplies of water have been obtained. In general, there are thicker sections of till, clay, and silt in the northern half of the basin than in the southern half.

Young volcanic rocks (Qv) crop out in small areas in unhabited parts of the high Cascades. They undoubtedly are moderately porous and highly permeable, but are undeveloped. Their chief hydrologic significance is in supplying a base flow to streams draining them.



EXPLANATION

Qg

Glacial, interglacial, and postglacial deposits of Quaternary age.

Well-sorted sand and gravel yield moderate to large supplies depending chiefly upon saturated thickness.

Dissolved solids generally less than 150 mg/l. Excessive iron is a common problem. Saline water occurs at depth in some areas.

Volcanic rocks of Quaternary age.

Occurs only in mountains; important as a reservoir in headwaters of some streams.

Probably very low dissolved solids, excellent quality.

Volcanic flows and pyroclastics of Tertiary age.

Generally yields only small supplies.

Probably low dissolved solids, except where contaminated by saline water from marine strata.

Marine and continental sedimentary rocks of Tertiary age.

Low porosity and permeability, yields small supplies.

Shallow water generally low in dissolved solids; deeper wells may yield saline water.

pT

Metamorphic, igneous, and sedimentary rocks of pre-Tertiary age and Tertiary intrusives.

Generally low porosity and permeability, and will yield only small supplies.

Shallow water chiefly low dissolved solids; deeper water may be highly mineralized.

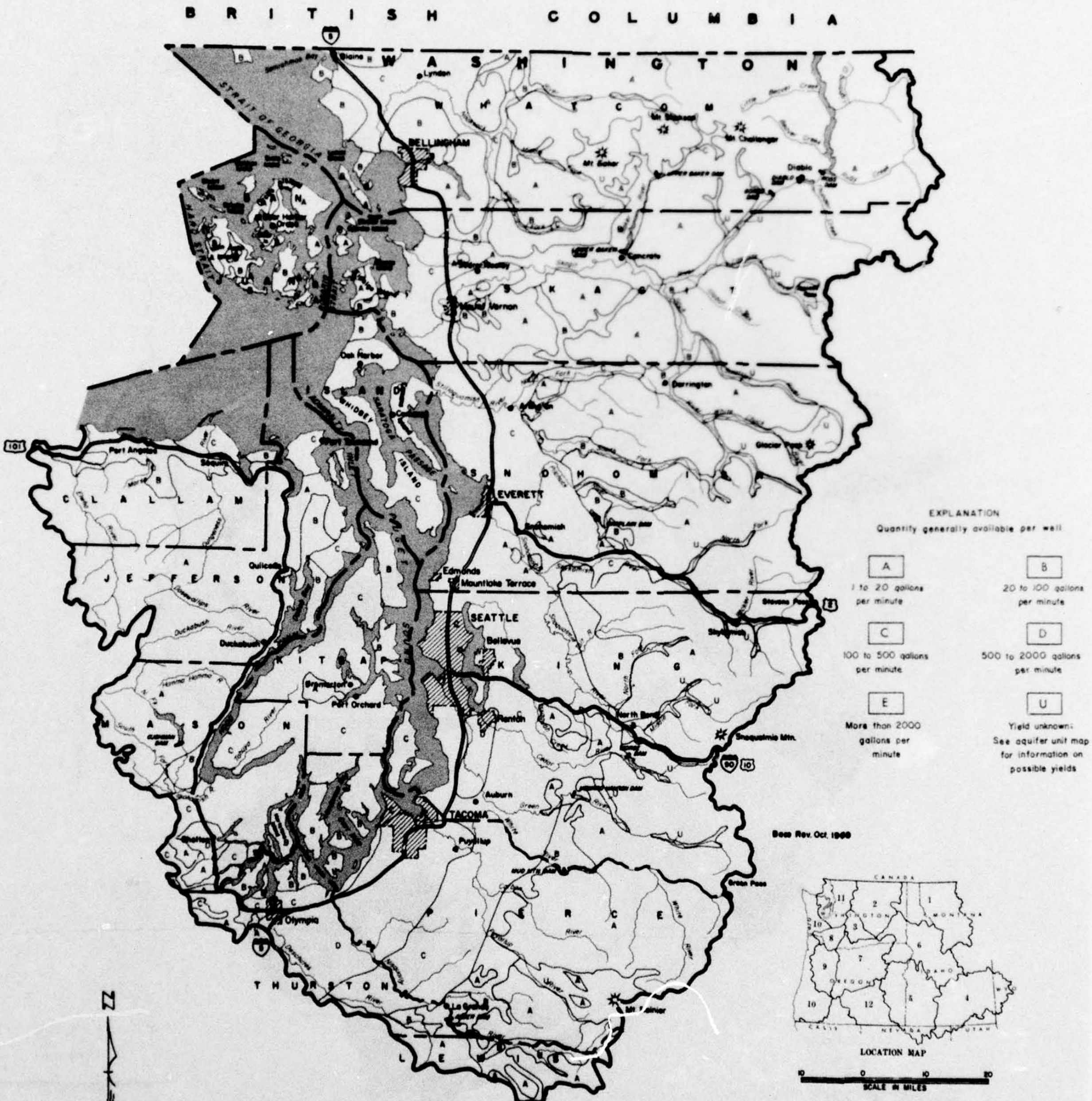
COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

AQUIFER UNITS

PUGET SOUND SUBREGION 11

1968

FIGURE 856



LIMITS OF YIELD

The map shows areas where properly located and properly constructed wells generally are capable of yielding amounts of water within the limits specified in the legend above.

The map does not indicate the total quantity of water that may be safely developed in any given area or aquifer; these determinations generally can be made only on the basis of special investigations.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER

PUGET SOUND SUBREGION 11

1968

FIGURE 857

The older volcanic rocks (Tv) crop out chiefly in the foothills and mountains and generally are greatly altered. The pores, joints, and other fractures also are commonly filled by secondary minerals. Unweathered rock is exposed in canyons and on other steep slopes, but on gentler slopes a thick soil and subsoil overlie the parent rock. The unweathered rock generally has a very low porosity and permeability but the weathered mantle is considerably more porous and permeable and will generally yield small, and locally moderate supplies, to springs and wells in the foothills.

The consolidated sedimentary rocks (Tos) also crop out chiefly in the foothills and mountains and have low porosity and permeability. The weathered zone of this unit probably is less productive of water than the weathered volcanic rocks, and yields generally are small to very small. Moderately to highly mineralized water is common in deep wells and is encountered locally in wells less than 100 feet deep.

Older consolidated and crystalline rocks (pT) form the core of the Olympic Mountains, the Cascade Range north of Snoqualmie River, and most of the San Juan Islands. These rocks generally have low porosity and permeability and yield only small supplies to wells. However, a fairly thick zone of weathered material with talus, landslide, and debris detritus forms a shallow ground-water reservoir that is important in maintaining the base flow of streams.

The descriptions of the aquifer units, their general hydrologic characteristics, and the general quality of the water yielded by them are given in table 471. The general availability of ground water is shown on a map, figure 857. For maximum utility, that map and the aquifer unit map, figure 856, should be used together.

Generally, the yield range for wells finished in alluvial and glaciofluvial deposits in the upper reaches of streams draining the Cascade Range has been shown, on figure 857, as "20 to 100 gpm" or "unknown." These designations were based on small amounts of well data or no data. At many places the deposits are very coarse and, if even a few tens of feet of coarse material are saturated, yields of several hundred to a thousand gallons per minute could be obtained from properly constructed wells.

Table 471. Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 11

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qg: Glacial, interglacial and post glacial deposits of Quaternary age.	Interbedded, and interfingering glacial and interglacial deposits. Outwash sand and gravels; fluviatile gravel, sand, and silt; glacio-lacustrine fine sand, silt, and clay. Unstratified glacial drift and till. Poorly to well sorted; bedding ranges from finely laminated silts and clays to nonbedded drift and till.	Outwash sand and gravel and alluvial sand and gravel are highly permeable at many places. Yields of better wells range from 1000 to several thousand gpm with small drawdowns. Specific capacities 20 to 500 gpm per foot. Finer-grained deposits yield less. Major aquifer unit in subregion. Can support large additional development.	Dissolved solids generally less than 150 mg/l, rarely exceed 250 mg/l. Water mostly soft to moderately hard, fluoride low. Excessive iron is a common problem. Water generally calcium magnesium bicarbonate type.
Qv: Volcanic rocks of Quaternary age on Mount Rainier, Glacier Peak, and Mount Baker.	Chiefly pyroxene andesite, andesite breccia; some pyroclastic rocks, interbedded mudflows, and glacial deposits.	Apparently porous and permeable; serves as storage for melt water on Mount Baker, Glacier Peak, Mount Rainier; helps maintain late season flow of streams draining these areas. No wells in unit.	No data available. Analyses of surface water draining areas indicate very low dissolved solids, generally soft water.
Tv: Volcanic rocks of Tertiary age.	Chiefly andesitic lava flows, flow breccias and interbedded pyroclastic and clastic rocks. Lavas jointed, vesicular, often platy; openings commonly filled by secondary minerals.	Generally low porosity and permeability. Well yields generally a few to a few tens of gallons per minute. Upper weathered zone serves as shallow aquifer for domestic wells, and to maintain base flow of streams.	No data available. Probably low dissolved solids except where contaminated by water from adjacent marine strata.
Tos: Marine and continental sedimentary rocks of Tertiary age.	Massive to thin bedded, tuffaceous to arkosic shale, siltstone, sandstone. Some conglomerate, carbonaceous shale, coal seams. Some interbedded lavas and pyroclastic rocks.	Low porosity and permeability. Yields range from inadequate (for domestic supply) to a few tens of gallons per minute; specific capacity rarely exceeds 1 gpm per foot. Base flow of streams draining unit generally is low.	Water quality ranges from good to acceptable. Water in many wells saline, or contains gas, sometimes excessive iron. Shallow wells generally have good quality water, deeper wells more saline water.
pT:			
In Cascade Range includes Paleozoic and Mesozoic sedimentary strata, Mesozoic metamorphic rocks and Mesozoic and Tertiary intrusive rocks.	Gneiss, schist, slate, greenstone, quartzite, marbel, metaconglomerate; granitic to dioritic intrusive rocks; limestone, graywacke, argillite, arkose, siltstone, and some interbedded volcanic rocks.	Few well data available. Generally low porosity and permeability and yields only small supplies for domestic use. Weathered zone, talus and other debris in mountains form shallow ground-water reservoir that maintains fair-weather flow of streams. Unweathered rock beneath stores and yields little water.	Shallow water is of good quality, low in dissolved solids, soft. Deeper water probably ranges widely in quality; some probably highly saline.
In Olympic Mountains includes Mesozoic to early Tertiary sedimentary strata, and some volcanic rocks.	Graywacke, interbedded slate, argillite, volcanic rocks; minor arkosic sandstone, conglomerate, altered basalt, flow breccia.		
In San Juan Islands includes Mesozoic and late Paleozoic sedimentary strata; some pre-carboniferous intrusive rocks.	Limestone, dolomite, graywacke, argillite, siltstone, sandstone, shale; phyllite, schist, greenstone, volcanic flows; dioritic intrusive rocks.		

Water in Storage

A rough estimate of the quantity of water stored, in a specified depth interval below the water table in each aquifer unit, is given in table 472. A depth interval of 50 feet was used for computing storage for all aquifer units.

Table 472 - Storage, Recharge, and Discharge of Ground Water in Aquifer Units, Subregion 11

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge	
	Sq.Mi.	Acres (1000's)	Specific Yield (percent)	Depth Interval (ft)	Water (1000's ac-ft)	Inches Over Area	(1000's ac-ft)
Qg	5,460	3,500	20	50	35,000	20	5,700
Qv	225	144	5	50	360	48	575
Tv	2,025	1,300	2	50	1,300	12	1,300
Tos	260	165	2	50	165	12	165
pT	5,220	3,340	2	50	3,340	12	3,340
Total (rounded)					40,000		11,000

The specific yield of the alluvial and glacial deposits (Qg) probably ranges from a few percent for clay and till to more than 30 percent for clean well-sorted sand or gravel. The average is estimated to be about 20 percent. The specific yield of the younger volcanic rocks (Qv) in Subregion 11 is unknown. However, similar rocks in Idaho have specific yields of about 5 percent, and possibly more, so that value was used for these volcanics in Subregion 11.

The older volcanic rocks (Tv), the consolidated sedimentary rocks (Tos), and the pre-Tertiary rocks (pT) have very low porosity and specific yield where they are not weathered. However, the zone of weathering on gentler slopes usually is several tens of feet thick and the water table generally is in this zone. The specific yield of the upper part of the weathered zone probably is as much as 10 to 15 percent at places. The specific yield decreases greatly with increased depth and generally is less than 1 percent a few feet below the base of weathering. The value of 2 percent assigned thus is an estimate based on an assumed range in the profile of a maximum of 10 percent to a minimum of less than 1 percent.

It is estimated that 35 million acre-feet of water are stored in the first 50 feet of alluvial and glacial material (Qg) below the water table. Storage in the upper 50 feet of saturated material of other aquifer units is estimated to be about 5 million acre-feet.

Natural Recharge and Discharge

Recharge to aquifers in Subregion 11 is entirely from precipitation. Recharge to the alluvial and glaciofluvial aquifer unit (Qg) is generally from direct precipitation; however, at some places streams draining upland till plains are influent to more permeable aquifers in other parts of their courses. The consolidated rock units, Tv, Tos, and pT are recharged entirely by direct precipitation.

During the low-rainfall months of July and August there is very little recharge. Generally, the moisture from all but the greatest storms during that period is absorbed by the soil zone and is evaporated or transpired without reaching the water table. Water levels generally begin rising during the period September-November, depending on the prior soil-moisture depletion, thickness of the soil, depth of the water table below land surface, and other factors. Aquifers at many places in Subregion 11 are filled during the rainy season to the point where they are incapable of receiving and containing additional recharge; the surplus precipitation becomes "rejected recharge." Some shallow aquifers, including the near-surface permeable zones of the consolidated rocks, fill early in the winter and then water levels rise and fall with each storm. At some places deeper aquifers in the alluvial and glaciofluvial deposits never completely fill; hence, do not reject recharge. An examination of hydrographs of wells suggests that average annual recharge to the alluvial and glaciofluvial aquifers may be on the order of 24 inches of water. Hydrographs of a few representative observation wells in these deposits are given in figure 858.

In contrast to recharge, which is an intermittent process, natural discharge is a continuous process. Maximum discharge occurs when the hydraulic gradient is steepest, and, except for short periods, mainly in areas adjacent to flood plains, the gradient is steepest when the water table is highest. Base flow supplied by ground water to streams during prolonged dry periods often represents minimum ground-water discharge.

Stream-discharge hydrographs were examined for separation of the ground-water component of discharge and flow-duration curves were constructed for representative streams, as described in the Regional Summary, to determine the ground-water component of streamflow. Generally, the ground-water component of discharge

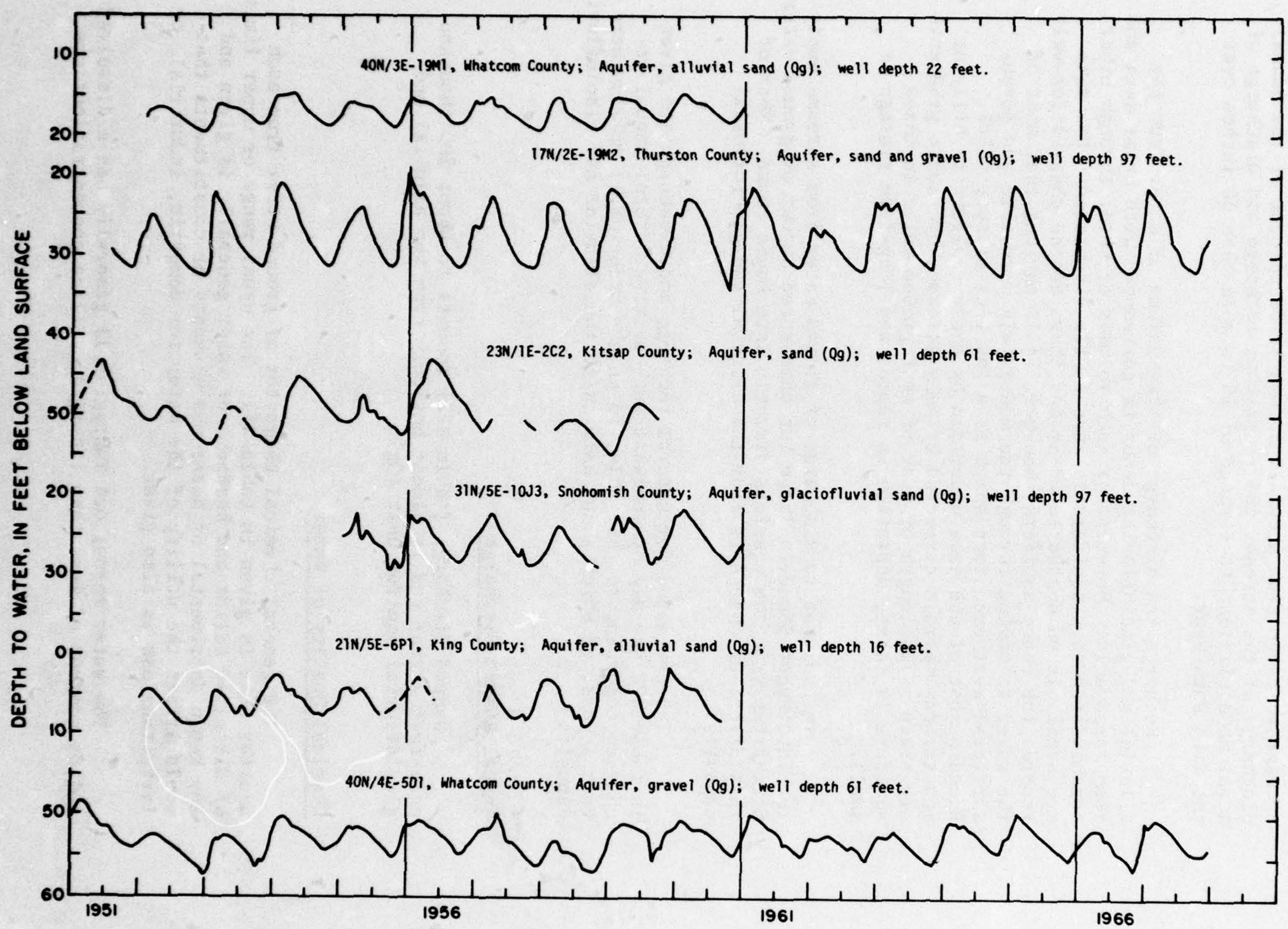


Figure 858 Hydrographs of selected wells in subregion

appears to range from about 25 to nearly 50 percent of the annual discharge of the stream, and represents recharge and discharge of a volume equivalent to a range of 18 to more than 30 inches over the area each year.

Recharge and discharge of that volume of water from the alluvial and glaciofluvial deposits correspond with other data and seem reasonable. Movement of such volumes of water through other consolidated-rock aquifers is less easily visualized. Few data are available on depths to water and there are no observation-well records for those aquifers; however, it is obvious that most of the water is moving through the moderately permeable and porous surficial weathered zone which is a few tens of feet thick. Because most of the area underlain by these aquifers is hilly or mountainous terrain dissected by many streams, hydraulic gradients are steep. The length of stay of most ground water in these aquifers is short, depletion is rapid, and long-term storage is small.

In addition to discharge of ground water from streams emptying into Puget Sound, a large but unmeasured amount of ground water discharges from the aquifers directly into Puget Sound. Most of this direct discharge is from the alluvial and glaciofluvial deposits.

The estimates for natural recharge and discharge are given in table 472 and may be somewhat conservative. Total annual recharge, according to the table, is on the order of 11 million acre-feet a year, of which about half is to the alluvial and glaciofluvial deposits.

Annual Pumped Discharge

Pumped discharge (table 473) amounts to about 200 thousand acre-feet a year and is almost entirely from the alluvial and glaciofluvial aquifer unit (Qg).

Chemical Quality of Water

The general chemical character of ground water from each aquifer unit is given in table 471. The usual range or upper limit of dissolved solids and hardness of water generally is given and any known detrimental or hazardous elements or constituents that would affect the utility of the water for domestic, industrial, or irrigation use is also given.

The water throughout Subregion 11 generally has a dissolved-solids content of less than 150 mg/l. Silica concentrations are

Table 473 - Ground-Water Withdrawal and Consumptive Use
Subregion 11, 1970

	Ac-ft per year; all quantities in thousands
Irrigation	
Acres irrigated	20
Withdrawal	30
Consumptive use	20
Industrial1/	
Withdrawal	37
Consumptive use2/	1.8
Public Supplies	
Persons served	470
Withdrawal	100
Consumptive use3/	20
Rural-Domestic	
Persons served	275
Withdrawal4/	31
Consumptive use5/	15:5
Stock	
Withdrawn and used6/	4.6
Total withdrawal (rounded)	200
Total consumptive use (rounded)	60

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated to use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

generally in the range from 20 to 60 mg/l, and the water is soft to moderately hard. Excessive iron probably causes more problems than any other constituent or characteristic. Temperatures generally range from about 48° to 55°F.

Chemical analysis of ground water and a discussion of ground-water quality are included in most of the areal reports listed earlier. Most of those analyses and additional ones are included in a report by Van Denburgh and Santos (175).

Present Use and Future Availability

Estimates of present use of ground water are based on data for 1965 to 1967, projected to 1970. Projection of public, domestic, and industrial use is on the basis of estimated population growth. Irrigation use was projected on the basis of past rates of increase, modified for special situations. Ground-water withdrawal and the amount used consumptively are given in table 473. Annual ground-water withdrawal and annual consumptive use of ground water in Subregion 11 are estimated to be about 200 thousand and 60 thousand acre-feet respectively.

Generally, in most areas where significant amounts of ground water are withdrawn, a large part of the water not used consumptively returns to the ground. However, in Subregion 11 some municipalities and industries discharge their wastes directly into Puget Sound. Consequently, where the source is ground water, depletion of the ground-water supply is considerably greater than consumptive use. Depletion by irrigation and domestic use in Subregion 11 probably is about equal to consumptive use. Average annual depletions of ground water in Subregion 11 are estimated to be about 140 thousand acre-feet. Nearly all withdrawals and depletions are from the Quaternary alluvial and glaciofluvial deposits (Qg).

Average annual recharge to the alluvium is estimated to be about 6.0 million acre-feet. The depletion by pumping, therefore, is only about 2 percent of average annual recharge. It is obvious that withdrawals could be increased severalfold without causing general depletion of the aquifer unit. However, local overdevelopment has been reported, and in a few small areas salt water has entered wells drilled near the shore of Puget Sound.

Only a small percentage of the wells drilled in consolidated rock aquifers (Tv, Tos, pT) yield more than 20 gpm; perhaps 10 percent yield more than this and 10 percent less than 1 gpm. Larger supplies of ground water generally can be developed only from the alluvial and glacial deposits. At many places much larger yields could be developed from these deposits than generally are obtained.

Where sand and gravel strata are thin, use of multiple-screen sections or gravel-walled wells may result in larger yields. In some upland areas, thick sections of till and clay are overlain by thin outwash sand and gravels. Many of these outwash deposits contain permanent perched ground water that might be developed by large-diameter shallow wells or infiltration trenches. Alluvial deposits occur along most stream courses, generally extending far upvalley into the mountains. Large-diameter shallow wells and infiltration trenches could be used to develop ground-water supplies in these areas also.

Artificial Recharge

Water pumped from wells and used in heat-exchange or air-conditioning installations is returned to the aquifer through recharge wells at several places in Subregion 11. Recharge of this type has been reported at Tacoma, Everett, and Snohomish. (125) So far as is known, there is no true artificial recharge in the sense of planned addition of water to an aquifer for the purpose of augmenting ground-water supplies.

The sand and gravel deposits at many places afford excellent opportunities for artificial recharge. However, ground water is a transient resource; artificial recharge would raise the water table, increase the hydraulic gradient, and result in increased discharge. The present natural annual recharge and discharge are many times the pumped withdrawal and, as was pointed out previously, much natural recharge is rejected in the late winter and spring. Artificial recharge under present conditions would not increase the available water supply except, perhaps, locally.

Water Rights

A total of 2,575 ground-water right-appropriation and declaration records in permit and certificate stages were on file with the Washington State Department of Water Resources for the Puget Sound Subregion as of April 30, 1967. Prime rights in this area allow summer-period withdrawals totaling 647,940 gpm (1,440 cfs). Nearly all of this quantity, 645,690 gpm, has a consumptive effect on the resource. The remainder, 2,250 gpm used in the operation of heat pumps, is considered to have a partially consumptive effect.

In addition, a total of 27,428 gpm has been allocated under appropriate rights that can be classified as supplemental.

Prime ground-water rights are listed in table 474, according to Water Resource Inventory Areas as defined by the State of Washington Department of Water Resources and shown on figure 776. More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 474 - Ground-Water Rights in the Puget Sound Subregion, 1967

Basin No.1/	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total2/
		(Gallons per Minute)						
01	Nooksack	7,570	81,635	8,669	1,670	20	1,702	93,600
02	San Juan	-	272	1,137	208	-	234	1,192
03,04	Skagit	16,925	33,108	8,348	3,750	-	839	59,317
05	Stillaguamish	5,550	8,266	645	5,000	20	-	17,116
06	Whidbey	890	4,564	9,704	1,043	-	930	13,654
07	Snohomish	5,902	13,122	9,401	3,522	80	1,201	33,280
08	Cedar-Sammamish	12,360	12,324	37,528	12,291	225	548	56,932
09	Green-Duwamish	2,897	8,104	30,568	1,695	-	1,124	41,338
10,12	Puyallup	82,365	25,304	70,580	46,676	605	3,094	199,216 3/
11	Nisqually	1,440	17,026	10,029	2,625	275	2,550	24,542
13	Deschutes	6,670	13,476	13,646	7,438	-	1,090	34,878
14	Shelton	4,200	2,312	9,138	12,545	10	1,007	26,358
15	Kitsap	4,082	3,996	16,205	3,612	417	64	25,858
16	E. Olympic Mts.	-	50	1,362	-	-	-	1,362
17	N.E. Olympic Pen.	2,250	2,114	1,519	-	1,110	-	5,798
18	Port Angeles Area	718	7,282	6,042	21	-	438	13,350
TOTAL		153,819	232,954	234,522	102,246	2,762	14,821	647,940

1/ Water resource inventory area number as shown in figure 776.

2/ The total prime rights do not agree with the sum of the uses because (1) only the most important or largest uses are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use.

3/ Approximately 30 percent of the developed ground water under recorded rights in the Puget Sound Subregion is in the Puyallup River Basin-Tacoma area.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

In subregion 11, streams draining the mountains derive about one-fourth to one-third of their annual discharge from ground water. The ratio of ground water to surface water generally ranges from a few percent during periods of high flow to 100 percent during low-flow periods. During a 120-day depletion (no recharge during the period) ground-water discharge declines to 12 to 15 percent of the discharge at the beginning of the period, indicating that in the mountains most of the ground water is in shallow, short-term storage. Ground-water discharge generally is greatest during the wet winter and spring months even though the percentage of ground water in the total discharge is lower. However, during infrequent periods of dry weather in these seasons, ground water may supply most of the streamflow for short periods. Bank storage probably is important along the mainstem of a river during major floods, but is a minor factor in the smaller tributaries. Even during major floods ground water probably is being added to the system by discharge into the hundreds of smaller streams that combine to form a major river. Hydrographs showing low-flow characteristics of selected streams are shown in figure 859.

Ground-water surface-water relations are more complex for streams draining areas at lower altitudes that are underlain by alluvial and glaciofluvial deposits. Most of the Puget Sound Basin consists of a gently rolling upland 100 to a few hundred feet above sea level, segmented by major streams flowing into Puget Sound. The stream valleys generally are only a few to a few tens of feet above sea level. The regional water table beneath some of the upland-bench segments is 100 to 200 feet below land surface. In general, wherever the regional water table is deep, there are one or more perched aquifers above the regional water table, and some of these are permanent major aquifers.

A stream draining one of the upland segments may gain water from a perched aquifer in one reach and lose it to the regional aquifer in another. At some places, streams gain from perched aquifers and lose to regional aquifers at the same place. During wet periods at some places, the water table is high enough to discharge temporarily into certain small streams that later become dry as the water level drops below the beds of the streams. Generally, where lowland streams are low enough to be perennial drains for ground water, the average annual discharge of ground water to these streams is on the order of 1 to 1.5 cfsm (cubic feet per second per square mile); on the order of 1.5 acre-feet per acre each year.

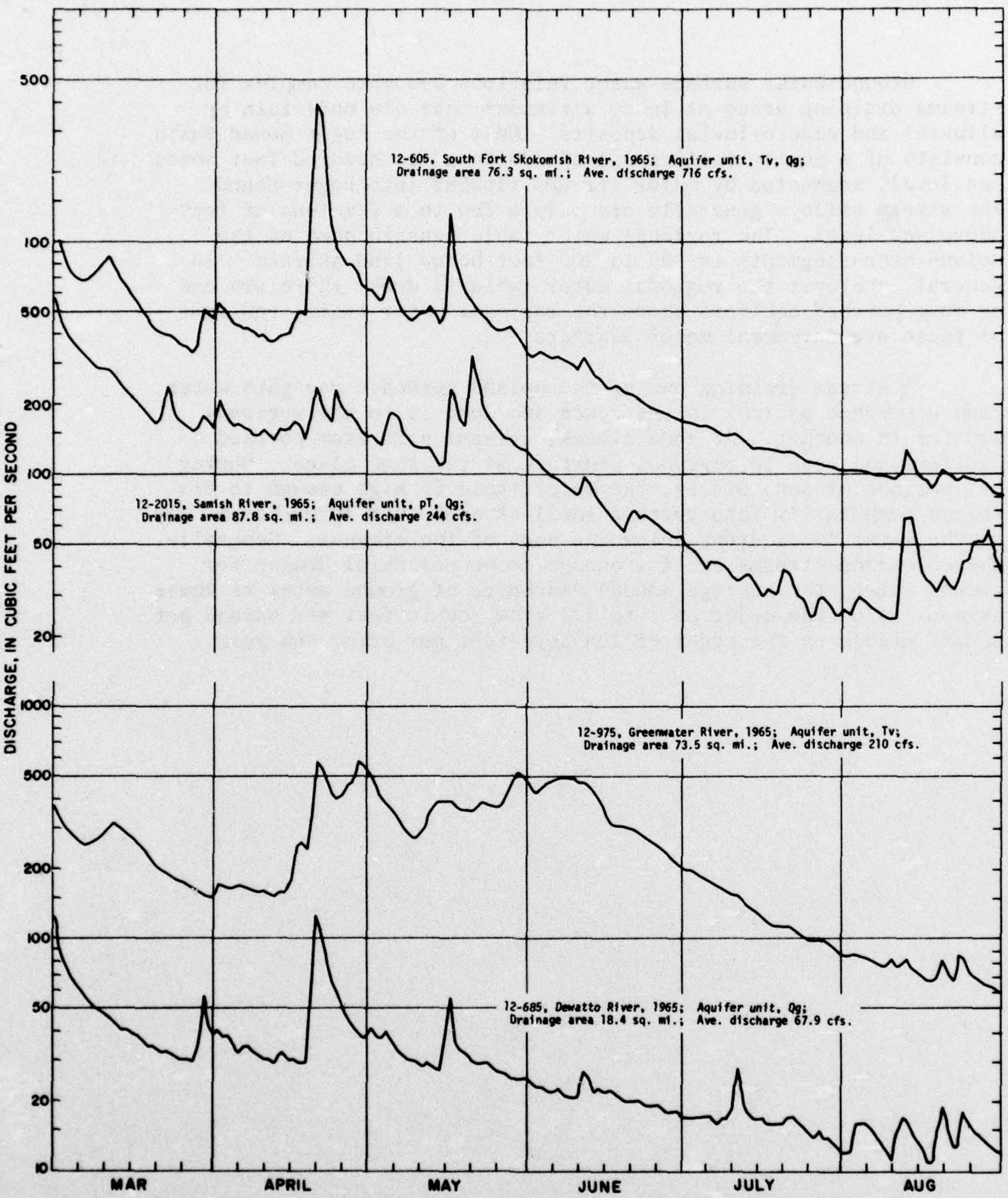


Figure 859 Hydrographs showing low-flow characteristics of selected streams

SUBREGION 12, OREGON CLOSED BASIN

HYDROLOGIC FRAMEWORK

The Oregon Closed Basin Subregion lies wholly within the State of Oregon and includes the southern part of the high central Oregon plateau. The subregion borders the northwest edge of the Great Basin and is enclosed by the Ochoco Mountains to the north, the Steens Mountains to the east, the Calico and Black Ranges to the southeast, the Warner Mountains to the south, and the Fremont Mountains to the west. There is no drainage to the sea. Streams drain into brackish landlocked lakes which lie between elevation 4,000 and 4,500 feet. The area covers 17,904 square miles, of which about 99 square miles are water and 17,805 square miles are land. The area represents about 6.5 percent of the total area of the region. Physiographic features of the subregion are shown on figure 1.

About 60 percent of the subregion, most of which is in the southern part, is characterized by its high basin and range topography with faults trending northeast and southwest. Young fault block mountains are separated by broad valleys containing alkaline lakes that are remnants of once much larger Quaternary lakes. Tertiary lava flows interbedded with pyroclastics underlie most of this area.

Bordering the basin and range area on the north is an east-west band 20 to 50 miles wide of high lava plains, a young, uneroded surface formed by a thick accumulation of predominantly Pliocene lava flows. The extreme northeast section of the subregion is mountainous terrain underlain by pre-Tertiary sedimentary and volcanic rocks of the Blue Mountains.

Soils over broad areas consist of loose, porous materials, largely of volcanic origin, which, in general, are shallow and support only sparse vegetation. The recent alluvial fans and flood plains originated from uplands and are composed mainly of volcanics and other sediments. Where water is available, these soils are used as cropland. However, in some of the lower lying areas near the lakes where seasonal water table fluctuations occur, the alluvial and lacustrine material is alkaline to strongly alkaline. Soils in the mountainous areas were developed from volcanic and old sedimentary rocks. The deeper and better soils support forests in those areas where there is adequate precipitation.

Annual runoff generated within the subregion averaged about 1.25 inches or 1,650 cfs for the period 1929 to 1958. A large percentage of the runoff occurs in the spring from snowmelt, with winter runoff from rainfall accounting for a much smaller portion. Summer flow in some of the major streams is steady due to the presence of springs.

Most perennial streams head in the mountains on the eastern and western borders of the subregion. These streams for the most part drain areas of less than 1,000 square miles each. Runoff enters shallow, landlocked lakes and is dissipated by evaporation. Because of evaporation and with the absence of external drainage, the lakes contain water of high mineral content. Some of the lakes, such as Malheur Lake and the upper lakes in Warner Valley, fill and spill into creeks or other lakes. These lakes are not as saline as those having no overflow, such as Abert, Alkali, Christmas, and Harney Lakes.

Much of the interior of the subregion has no perennial streams. Runoff from this area collects in intermittent lakes and either recharges ground water or evaporates.

The native cover is dominated by sagebrush, native grasses, and desert shrubs, which cover broad areas of the interior. Pondweed, tules, and other plants grow profusely and provide good feeding and resting areas for wildfowl in the less saline lakes and inflow areas to the lakes.

The forests are almost exclusively softwoods with small stringers of hardwoods in the valleys. The forest zone begins about 5,500 feet above sea level. Tree growth is limited by low moisture at low elevations. In the northern part of the subregion a belt of western juniper usually occurs between commercial forest land and the grass-shrub lands. Ponderosa pine dominates much of the forested area and often occurs in pure stands at lower elevations. As elevation increases and moisture conditions become more favorable, such species as Douglas-fir, white fir, alpine fir, lodgepole pine, and Engleman spruce occur. Extensive pure stands of lodgepole pine are often found at higher elevations in areas where fire, insects, or disease removed the original stands. Areas of grassland, occasionally exceeding 1,000 acres, are intermingled in the forest land zone.

The subregion is sparsely populated. Of the 13,300 people in the area in 1965, about 5,300 lived in the Burns-Hines area of north-central Harney County.

CLIMATE

The Oregon Closed Basin has a semiarid climate, with long, rather severe winters and short summers with many clear days. Night temperatures are relatively cool throughout the year because of the high elevation of the basin.

Although most of the air masses reaching Subregion 12 have their source over the Pacific Ocean, they are much drier than the original maritime air and reflect the temperature of the lands over which they travel. However, this air of marine origin usually has a moderating influence on the temperature extremes throughout the area. Occasionally, however, cold arctic air from Canada will reach the subregion, causing extremely cold winter weather.

Precipitation

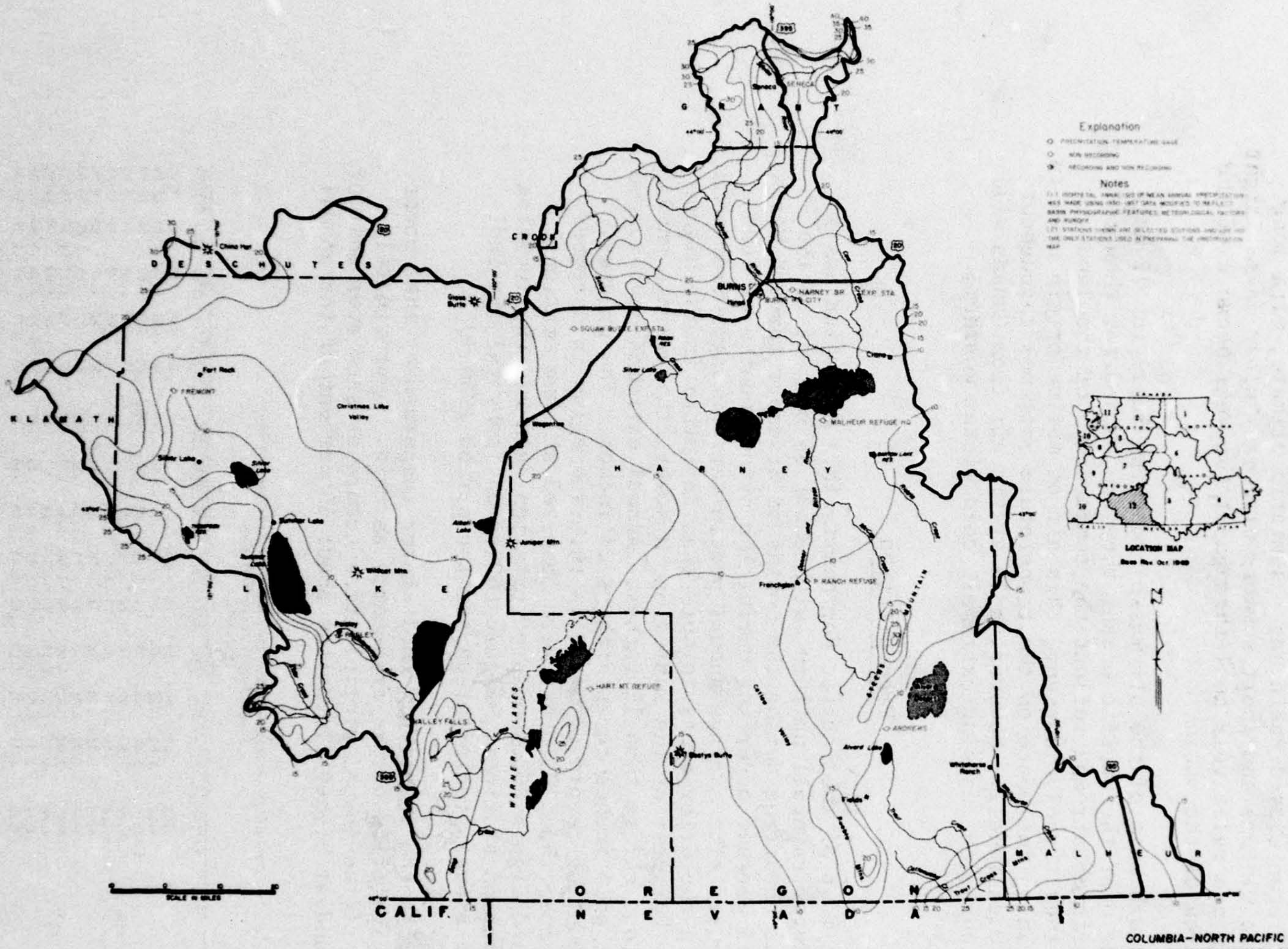
Like most of the Pacific Northwest, this subregion has a definite winter rainfall pattern, with about 55 percent of the annual total occurring during the months of November through March, and about 15 percent occurring during the summer months of June through August. The average annual precipitation ranges from about 10 inches in the drier areas to more than 25 inches in the higher mountains. For most of the subregion, however, the average annual precipitation is less than 12 inches. Annual extremes have ranged from less than 4 inches to as high as 27 inches. The greatest monthly amount of record occurred in this subregion in December 1964, when more than 10 inches were observed at some stations. Table 475 and figure 860 show precipitation data and the location of precipitation stations. Figure 860 is an isohyetal map indicating mean annual precipitation for the period 1930-1957.

Despite the relatively cool winter temperatures that occur, winter precipitation occurs frequently as rain. Approximately 40 percent of the annual precipitation occurs as snow over most of the area, and at higher elevations about 65 percent of the annual

Table 475 - Average Monthly and Annual Precipitation (Inches)
Oregon Closed Basin Subregion
1931-1960

Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Andrews 1/	4100	.80	.80	.59	.78	.64	.59	.21	.22	.42	.69	.73	.66	7.13
Burns WB City	4151	1.62	1.27	.97	.75	.89	.88	.34	.29	.50	.86	1.16	1.43	10.96
Fremont	4512	1.48	.98	.78	.61	1.12	.93	.37	.26	.42	.83	1.07	1.64	10.49
Harney Branch Exp. Sta. 1/	4139	1.12	.97	.76	.74	.78	.80	.17	.21	.37	.74	1.07	1.21	8.94
Hart Mountain Refuge 1/	5616	.85	.76	.96	.73	1.82	1.56	.37	.29	.48	.96	.78	.83	10.39
Malheur Refuge 1/	4109	.93	.79	.78	.51	1.15	.97	.31	.22	.55	.87	1.00	.92	9.00
Paisley	4360	1.23	1.01	.90	.67	1.25	1.13	.37	.27	.43	.82	.85	1.16	10.09
P Ranch Refuge 1/	4205	1.02	.88	1.00	.93	1.88	1.44	.23	.27	.47	.96	1.12	1.17	11.37
Seneca 1/	4666	1.75	1.17	1.19	.97	1.19	.94	.32	.33	.64	.89	1.02	1.54	11.95
Squaw Butte 1/	4675	1.31	1.07	1.00	.72	1.44	1.24	.25	.47	.54	1.05	1.10	1.37	11.56
Valley Falls	4326	1.41	1.31	1.12	.96	1.43	1.38	.30	.29	.57	1.11	.99	1.50	12.37

1/ Period is shorter or longer than the 30-year normal.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

OREGON CLOSED BASIN
SUBREGION 12

1968

FIGURE 860

total occurs as snow. The first snowfall usually occurs by early October and normally none may be expected after May 1. Winter snowfall ranges from 25 to 50 inches on the main body of the plateau and exceeds 150 inches at the higher elevations. Snowpack depths rarely exceed 15 to 20 inches, but maximum depths of 35 inches on the plateau floor to 68 inches at the higher elevations have been observed. Density of the snowpack increases from approximately 25 percent water equivalent in early winter to about 40 percent in April.

Temperature

During the warmest summer months, average maximum temperatures are in the upper 80's on the plateau floor. Temperatures over 100°F. have been recorded at most stations in the subregion, with a recorded high of 109°F. at Fremont. See table 476 and figure 860 for temperature data and locations of weather stations. Temperatures reach 90°F. or higher for periods of 20 to 30 days annually at lower elevations and for periods of 5 to 15 days at the higher elevations. Average minimum summer temperatures range from the mid-30's to mid-40's.

Night temperatures are comparatively cool, with subfreezing temperatures occurring an average of 175 to 275 days annually, depending on elevation. Subfreezing temperatures may be expected during any month of the year.

In winter, average maximum temperatures range from the upper 30's to lower 50's and average minimum temperatures range from 15° to 25°F. Temperatures below zero occur nearly every winter and minimum temperatures less than -25° have been recorded at most stations, with a record low of -54° recorded at Seneca. The coldest weather occurs when cold arctic air, which usually moves southward from Canada along the east slope of the Continental Divide, breaks across the Rockies and then moves southward between the Rockies and Cascades into the subregion.

The growing season on the plateau floor ranges from 80 to 140 days. The last freezing temperature in spring and the first in fall usually occur in June and September, respectively.

Wind

Prevailing winds in this area are north or northwest, but this predominance is much less in winter than in other months. During periods of winter storms, the more extreme winds are likely and are most frequent from the south or southwest.

Table 476 - Average and Extreme Temperatures (°F), Oregon Closed Basin Subregion

Station (Years of Record)	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Andrews	Av. Max.	39.6	44.5	53.2	61.5	71.0	80.3	91.1	88.3	77.1	65.5	51.9	41.8	63.8
(24)	Av. Min.	18.3	22.6	27.3	32.2	39.2	46.2	53.6	50.8	41.7	33.3	24.6	20.2	34.2
	Mean	29.0	33.6	40.2	46.8	55.1	63.2	72.4	69.6	59.4	49.4	38.2	31.0	49.0
	Highest	69	69	76	88	93	106	107	105	98	92	75	67	107
	Lowest	-32	-24	3	12	18	27	33	26	12	8	-9	-26	-32
Burns WB City 1/	Av. Max.	34.6	40.9	47.5	58.6	66.7	73.6	85.7	83.5	76.3	63.3	47.5	38.1	59.7
(18)	Av. Min.	14.5	20.1	24.8	31.5	38.5	43.7	51.1	48.9	40.9	32.5	24.3	18.9	32.5
	Mean	24.8	29.7	37.4	46.0	53.4	59.8	69.5	67.2	58.8	48.4	36.1	29.1	46.7
	Highest	58	64	74	86	93	95	103	100	100	86	70	61	103
	Lowest	-25	-18	-3	14	19	28	34	31	24	13	-17	-8	-25
Fremont 1/	Av. Max.	38.2	42.7	49.4	57.5	66.0	73.7	85.3	83.0	74.5	63.5	48.8	39.8	60.2
(39)	Av. Min.	13.6	17.8	21.5	23.6	31.6	33.5	36.3	34.1	28.6	23.8	19.9	15.7	25.0
	Mean	25.8	30.5	35.3	41.2	47.9	53.3	60.7	58.5	52.4	44.0	34.5	29.0	42.8
	Highest	82	67	79	84	93	101	109	101	102	86	74	68	109
	Lowest	-34	-39	-30	0	4	10	14	14	3	-2	-29	-40	-40
Harney Branch Exp. Sta.	Av. Max.	33.1	38.8	48.7	60.1	68.6	75.3	87.6	85.3	75.7	63.4	47.3	36.0	60.0
(23)	Av. Min.	10.3	16.8	24.1	29.1	34.8	39.7	45.1	41.9	34.2	27.0	21.0	15.0	28.2
	Mean	21.7	27.8	36.4	44.6	51.7	57.5	66.4	63.6	55.0	45.2	34.2	25.5	44.1
	Highest	57	68	76	86	92	102	105	101	99	87	70	61	105
	Lowest	-44	-36	-5	9	11	19	24	23	2	3	-15	-45	-45
Hart Mt. Refuge	Av. Max.	36.9	39.7	44.1	53.9	61.3	68.6	81.1	79.5	71.7	60.1	47.7	41.1	57.1
(20)	Av. Min.	17.0	20.9	22.9	28.2	33.6	37.9	44.1	42.7	37.9	31.6	24.6	20.7	30.2
	Mean	27.0	30.3	33.6	40.9	47.4	53.3	62.6	61.2	54.9	46.0	36.2	31.0	43.7
	Highest	57	62	69	78	85	96	98	94	97	81	71	68	98
	Lowest	-23	-17	-2	9	12	20	26	25	13	10	-10	-13	-23
Malheur Refuge Hdg.	Av. Max.	36.5	41.9	49.5	60.3	67.8	74.5	85.6	83.9	76.4	64.1	48.6	40.3	60.8
(23)	Av. Min.	16.2	21.8	25.2	30.7	37.8	43.3	49.6	46.2	38.4	30.9	23.7	20.3	32.0
	Mean	26.5	31.8	37.3	45.6	52.8	58.9	67.6	65.1	57.4	47.5	36.1	30.4	46.4
	Highest	59	62	75	86	92	98	100	98	100	90	74	65	100
	Lowest	-29	-16	-2	16	17	27	32	29	18	9	-18	-7	-29
Paisley	Av. Max.	40.5	45.9	52.1	60.4	68.3	75.6	86.5	85.3	76.6	65.1	50.9	43.4	62.6
(35)	Av. Min.	20.1	24.9	27.9	32.6	37.8	43.4	49.9	47.9	41.7	34.1	27.1	22.5	34.2
	Mean	30.3	35.4	40.1	46.5	53.1	59.5	68.2	66.4	59.1	49.6	39.0	33.0	48.4
	Highest	65	70	82	85	93	102	103	103	99	91	78	70	103
	Lowest	-29	-19	3	8	15	20	27	21	17	8	-11	-25	-29
Seneca	Av. Max.	34.8	39.0	45.9	54.8	62.6	72.7	83.9	80.6	73.6	62.3	48.3	39.9	58.2
(21)	Av. Min.	7.0	9.1	16.2	26.3	30.9	34.2	37.0	33.1	26.6	22.1	15.1	11.3	22.4
	Mean	23.6	24.1	31.0	40.5	46.8	53.5	60.4	56.9	49.9	42.2	31.5	25.6	40.5
	Highest	58	59	74	83	89	104	104	100	96	85	72	58	104
	Lowest	-43	-54	-26	5	11	13	19	13	1	-1	-31	-38	-54
Squaw Butte Exp. Sta.	Av. Max.	34.8	39.8	46.7	57.6	65.3	72.2	85.0	83.0	75.3	62.4	46.9	38.5	59.0
(22)	Av. Min.	15.1	19.7	23.6	29.1	35.4	40.7	48.9	47.2	41.1	32.9	23.9	19.8	31.5
	Mean	24.9	29.7	35.3	43.3	50.4	56.5	67.0	65.1	58.2	47.6	35.4	29.0	45.2
	Highest	60	66	72	81	89	97	102	97	104	89	75	64	104
	Lowest	-24	-18	-2	11	14	22	29	29	20	10	-13	-14	-24
Valley Falls 1/	Av. Max.	40.2	44.1	51.1	59.7	66.6	76.1	87.5	86.1	76.8	64.8	51.2	42.5	62.2
(44)	Av. Min.	20.0	24.0	26.5	30.4	35.2	40.0	44.7	42.8	36.6	30.9	25.0	21.7	31.5
	Mean	29.7	33.1	38.1	45.1	51.6	57.7	65.9	63.8	56.7	47.9	37.6	32.6	46.7
	Highest	65	70	78	85	92	102	105	105	102	91	78	72	105
	Lowest	-39	-26	-7	5	14	20	25	22	8	3	-19	-34	-39

1/ The mean temperature is for the normal period 1931-60, other data are for period of record.

Evaporation

Substantial evaporation occurs during the summer months due to comparatively warm days and clear skies. Annual evaporation from a Class A pan is estimated at 55 to 60 inches and evaporation loss from lakes and reservoirs is estimated at 39 to 42 inches annually. The annual potential evapotranspiration varies between 22 and 24 inches. The computed annual evapotranspiration is 6 to 8 inches and 10 to 12 inches for soils with 2-inch and 6-inch moisture holding capacities, respectively.

Humidity

Relative humidity in early morning hours ranges between 80 and 90 percent throughout the year. Humidity in this range is common almost any time of the day in late fall and winter. In contrast, the average relative humidity during July varies from 50 percent in early morning to 20 percent in late afternoon, with afternoon humidity of 10 percent or lower not uncommon.

Sunshine

During the winter this subregion has predominantly cloudy weather. In January the sun shines about 50 percent of the time possible and several consecutive days of fairly clear, sunny weather are not unusual. In the summer, the amount of time of sunshine increases to 80 to 90 percent of the total time possible.

SURFACE WATER

Principal streams within the subregion are the Silvies River, draining the northeast portion of the subregion; the Donner und Blitzen River, draining the west side of the Steens Mountain; Silver Creek, Chewaucan River, and Deep Creek, draining the west side of the subregion. Silvies River, draining 934 square miles at the gaging station near Burns, is the largest stream in the Oregon Closed Basin.

The major use of water is for irrigation. Thompson Reservoir, located in the upper reaches of Silver Creek, provides storage for irrigation purposes.

Quantity

Average annual runoff generated within the subregion is about 1,650 cfs or 1.19 million acre-feet. This averages 0.09 cfs per square mile.

Present Utilization

About 41 percent (680 cfs) of the mean discharge was withdrawn in 1965 for consumptive needs (rural, public supplies, self-supplied industrial use, irrigation, and recreation), but less than 25 percent (410 cfs) was actually consumed. Of the total water withdrawn, 625 cfs, or 92 percent, was for irrigation and 46 cfs was for self-supplied industry. Irrigation is also the major consumer, using 400 cfs of the 410 cfs consumed in the subregion.

The principal nonconsuming uses of water are for fish and wildlife and recreation. The nonconsuming uses are instream uses, except for the diversions of about 50 cfs required for operation of the Malheur Wildlife Refuge. These diversions to the refuge are used to create nesting areas and feeding grounds for waterfowl, and are in addition to the diversions made to irrigate lands in the refuge. Other nonconsuming uses such as hydroelectric power generation and dilution of wastes are minor or nonexistent at present.

Stream Management

The water requirements of various water uses are met from unregulated streamflow on all streams except Silver Creek. Thus, stream management consists almost entirely of scheduling diversions according to availability of natural runoff.

Impoundments There is only one reservoir having a usable capacity of 1,000 acre-feet or more. Thompson Reservoir, located on the upper reaches of Silver Creek in Lake County, has a total capacity of 21,500 acre-feet and was built for the purpose of storing water for irrigation. In Warner Valley, some of the marshes and lakes are diked and the water levels controlled, and in dry years some of the lower or northern lake beds are irrigated.

Diversions Major diversions are for irrigation. In recent years diversions for waterfowl propagation have increased during the fall and spring and have affected the levels of various lakes. Most of the streamflow in the principal river basins is diverted during the irrigation season.

Water Rights

The Water Resource inventory areas for Subregion 12 are shown on figure 861.

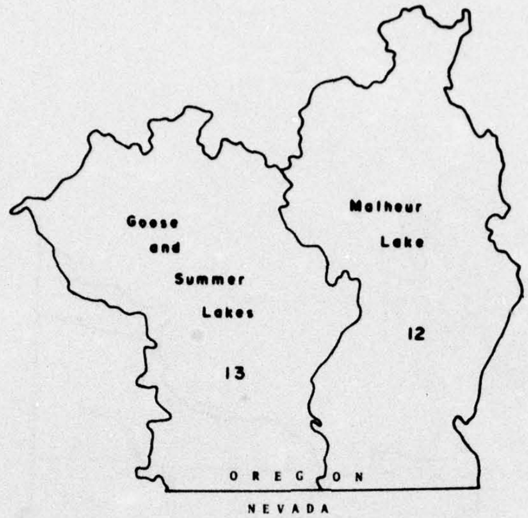


Figure 861 Map showing water resource inventory areas defined by the State of Oregon Water Resources Board

Discharge

The base period selected for the Columbia-North Pacific Region study is the 30-year period 1929 to 1958. A typical Subregion 12 stream, Chewaucan River near Paisley, Oregon, has a base period mean discharge close to 100 percent of its 47-year mean. Weather records show that precipitation at Valley Falls during the base period is also close to 100 percent of the 55-year mean.

Measurement Facilities Table 477 is a summary of streamflow data for the seven sites selected for detailed study in Subregion 12.

Figure 862 shows the locations of the selected sites, with Geological Survey identification numbers. The first two digits of the identification number, part number (10), have been omitted because Subregion 12 lies wholly within the area the Geological Survey designates as Part 10, the Great Basin.

Table 477 - Streamflow Summary for Selected Sites, Subregion 12

Stream	Station	Station Number	Gage Datum	Drainage Area (sq. mi.)	3/ Period of Record	1/ Annual Flow (cfs) Mean	Max.	Min.	2/ Momentary Flow Max.	Min.
Deep Creek	Adel	3715	4,965.7	249	29-65	120	251	24	9,420	1.7
Honey Creek	Plush	3785	4,550.4	170	30-65	25	61	3	11,000	0
Chewaucan River	Paisley	3840	4,430	275	24-65	139	341	32	6,490	0
Silver Creek	Silver Lake	3900	4,361.2	180	29-65	22	82	2	1,800	0
Silvies River	Burns	3935	4,195	934	22-65	164	375	15	4,960	0
Donner und Blitizen R.	Frenchglen	3960	4,254	200	37-65	116	201	49	2,750	6.6
Trout Creek	Denio, Nev.	4065	4,351.5	88	32-65	15	37	4	470	0

1/ Regulated values for base period (1929-58) with estimated 1970 conditions of development.
2/ Maximum or minimum observed instantaneous values for period of record.
3/ Other short periods of record prior to dates shown.

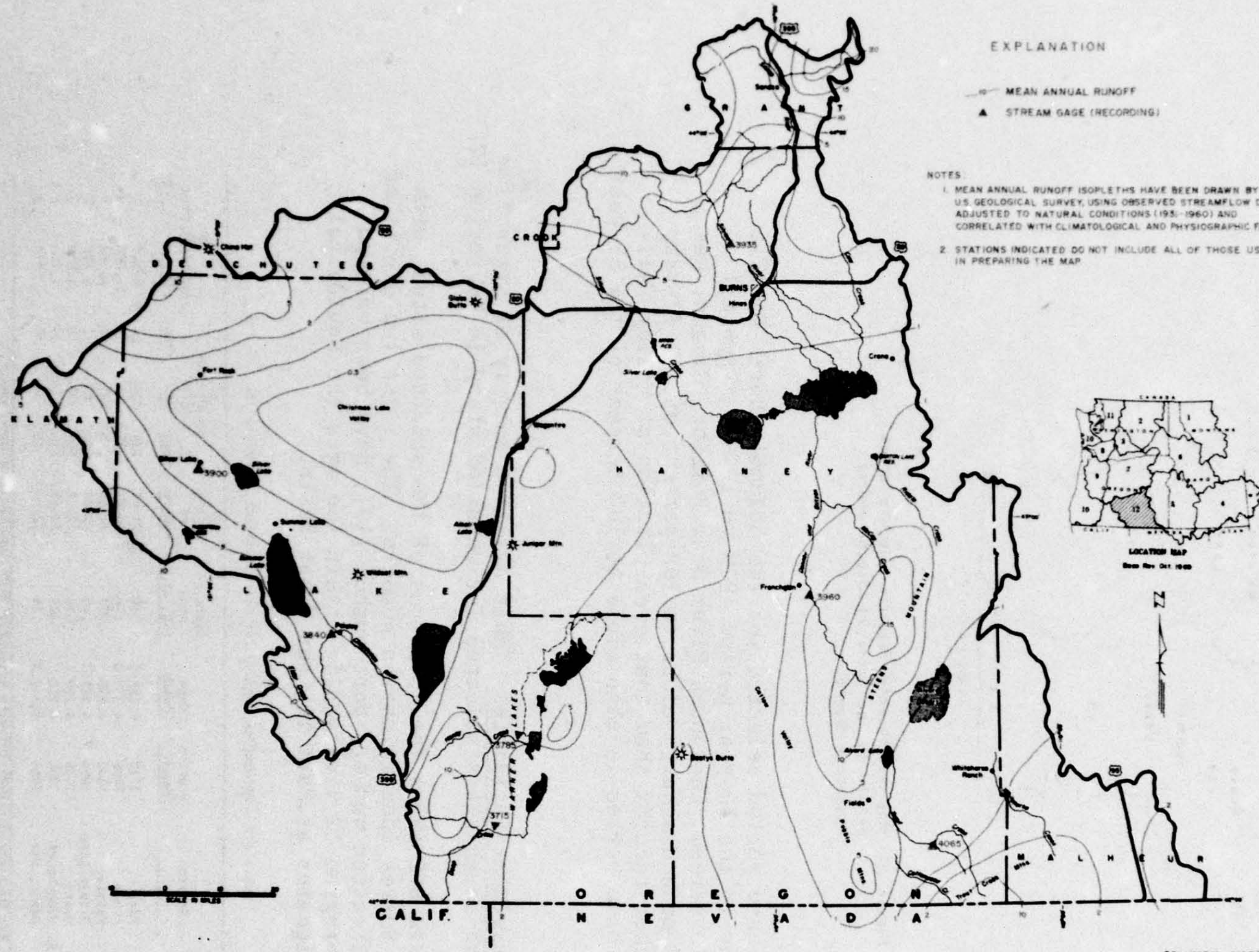
EXPLANATION

MEAN ANNUAL RUNOFF

▲ STREAM GAGE (RECORDING)

NOTES:

1. MEAN ANNUAL RUNOFF ISOPLETHS HAVE BEEN DRAWN BY U.S. GEOLOGICAL SURVEY, USING OBSERVED STREAMFLOW DATA ADJUSTED TO NATURAL CONDITIONS (1931-1960) AND CORRELATED WITH CLIMATOLOGICAL AND PHYSIOGRAPHIC FACTORS.
2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

OREGON CLOSED BASIN
SUBREGION 12

1968

FIGURE 862

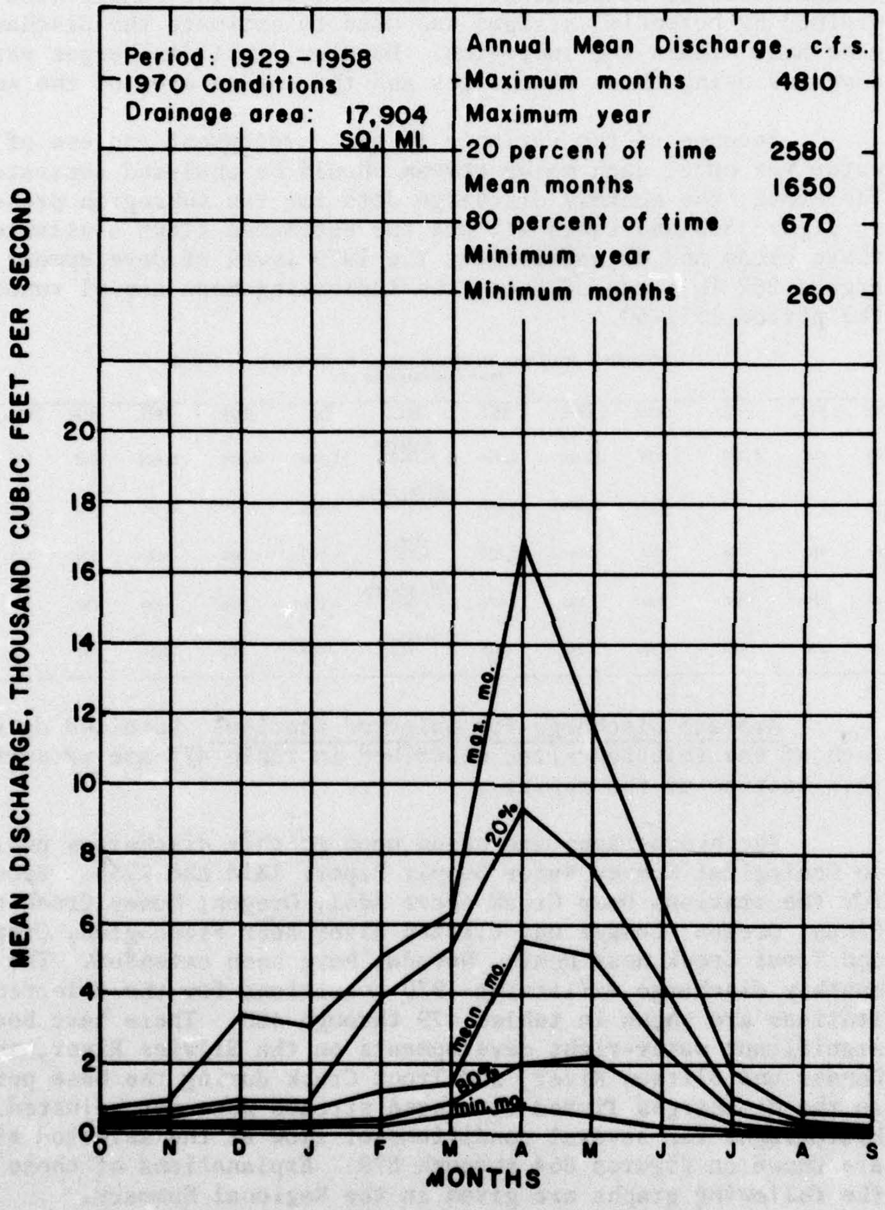


Figure 863 Monthly discharge, Oregon Closed Basin Subregion

Average Discharge for Subregion 12 An area of over 11,000 square miles of the subregion has no perennial streams. Runoff from this area collects in playas and either recharges ground water or evaporates. Therefore, only the runoff from areas drained by perennial streams was used to estimate the discharge generated within the subregion. However, unit discharges were computed using these discharges and the entire area of the subregion.

Because of the variance in the development and use of the water resource, each major stream should be analyzed separately. Therefore, the monthly discharge data for the subregion presented in figure 863 and table 478 are the estimated flows available from these areas and do not reflect the 1970 level of development. Figure 862 is a map of isopleths indicating mean annual runoff for the period 1931-60.

Table 478 - Discharge in Oregon Closed Basin Subregion, 1929-58
(Mean Discharge in cfs)

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
						Maximum						
660	880	3,530	3,030	5,090	6,320	16,860	11,690	6,660	1,820	610	510	4,810
						20 Percent						
440	610	930	910	1,870	3,340	9,290	7,550	4,270	1,070	400	340	2,580
						Mean						
350	450	720	690	1,180	2,220	5,510	5,070	2,490	620	260	260	1,650
						80 Percent						
240	280	290	330	370	820	2,000	2,150	960	280	150	160	670
						Minimum						
190	200	180	210	240	450	750	460	200	100	40	60	260

Average Discharge for Selected Stations Detailed data for each of the selected sites described in table 477 are presented in this section of the report.

The hydrographs are based upon monthly discharges published in Geological Survey Water Supply Papers 1314 and 1734. Records for the stations Deep Creek above Adel, Oregon; Honey Creek near Plush, Oregon; Donner und Blitzen River near Frenchglen, Oregon; and Trout Creek near Denio, Nevada, have been extended. The monthly discharge reflecting 1970 conditions for the selected stations are shown in tables 479 through 485. There have been no significant water-right developments on the Silvies River, the Donner und Blitzen River, and Trout Creek during the base period, so the discharges listed for these streams were not adjusted. Hydrographs for several conditions of flow at the selected sites are shown on figures 864 through 870. Explanations of these and the following graphs are given in the Regional Summary.

Frequency curve discharges for 1, 3, 6, and 12-month periods for high and low flows are shown on figures 871 through 877. The curves of low flows for Honey Creek near Plush are not shown for periods less than 12-month because of the very low flows which occurred.

Duration curves of mean discharge for 2-time periods, monthly and annual durations, are presented in figures 878 through 884.

Frequency curves of annual peak flows are shown in figures 885 through 890. The frequency curve for Silver Creek near Silver Lake is not included because the stream is regulated by Thompson Reservoir.

Dependable yield of the river basins is shown in tables 486 through 492. The table shows the lowest mean flow for periods of 1 through 10 consecutive years in the 30-year base period and their relationship to the 30-year mean.

Variations in Discharge Long-term variations in discharge and precipitation for two areas--Silvies River and Chewaucan River--are presented in figures 891 and 892. The means for the base period and the period of record as well as the 5-year moving averages are shown to provide comparison of base-period data to long-term data and to illustrate the general trend. Streamflow data are presented for water years, whereas precipitation data are presented for climatic years.

The ratio of the 30-year mean precipitation for the base period to the long-term record is 97 and 101 percent at Burns and Valley Falls, respectively; and the ratio of mean discharge for the base period to the long-term record is 103 and 101 percent for the Silvies River and Chewaucan River, respectively. The graphs also show that generally the maximums and minimums of record for both precipitation and discharge occurred during the base period. Thus, the selected base period should be representative of longer periods of time. The data presented do not indicate a long-term trend or rhythmic cycle of precipitation or discharge.

Variation in mean monthly and annual flows is depicted by the duration curves of flows in figures 878 through 884. These curves show the range in mean flows during the 30-year base period and the percent of time that any given mean flow has been equaled or exceeded.

Seasonal variations in runoff are clearly shown in the hydrograph of figures 864 through 870. The streams in the west side of the subregion generally have two peaks, one during the winter (usually December) and a larger one in the spring (occurring in April or May). The streams on the east side generally have only one peak, which occurs in the spring, usually April or May. The low runoff months throughout the subregion are usually July through November.

Streamflow Travel Time Time-of-travel studies have not been made for Subregion 12 streams.

River Profiles Profiles for the principal streams are shown in figure 893. The profiles were constructed from Geological Survey plan and profile sheet and quadrangle and topographic maps.

(Narrative continued on page 978)

Table 479 Modified Mean Discharges in CFS, Deep Creek Above Adel, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										8	5	4	
1929	12	16	22	13	8	70	78	171	60	8	4	4	39
1930	10	12	45	19	140	120	213	153	40	5	3	3	64
1931	10	12	12	12	25	73	89	43	6	1	1	2	24
1932	10	11	10	10	12	320	299	312	138	10	4	4	95
1933	10	14	8	7	8	19	158	162	140	8	3	4	45
1934	10	12	15	33	38	104	94	26	7	2	2	2	29
1935	5	14	21	20	27	66	607	442	156	13	4	5	115
1936	11	15	14	15	25	195	636	365	92	9	5	5	116
1937	11	12	12	14	11	37	425	285	68	6	3	4	74
1938	10	43	293	58	59	149	854	726	208	25	10	10	204
1939	22	35	34	20	20	211	254	102	18	5	4	4	61
1940	10	10	23	52	168	286	318	229	32	5	3	5	95
1941	12	22	28	21	62	241	209	369	161	23	10	14	98
1942	17	25	85	81	63	164	529	436	331	42	9	12	150
1943	16	58	119	101	85	542	799	494	474	74	17	17	233
1944	27	30	26	22	26	80	172	201	290	40	8	9	78
1945	14	29	40	73	154	87	295	624	237	27	8	10	133
1946	18	23	62	47	46	189	508	350	95	19	7	9	114
1947	18	28	34	23	68	126	193	160	128	9	4	7	66
1948	18	25	22	98	55	52	253	518	399	39	10	12	125
1949	20	29	25	29	23	65	652	420	110	12	8	11	117
1950	18	22	18	56	131	189	425	488	251	34	13	13	138
1951	24	51	128	44	230	194	609	458	124	19	12	14	159
1952	25	30	39	32	62	154	1072	754	320	90	23	26	219
1953	24	30	34	176	150	142	338	534	488	114	28	20	173
1954	24	53	60	45	132	237	471	333	125	23	13	16	128
1955	20	25	22	18	19	43	159	365	189	25	8	9	75
1956	14	33	417	301	95	338	677	729	312	54	20	22	251
1957	39	59	116	40	255	332	362	516	215	23	13	16	166
1958	36	43	35	94	412	118	580	857	264	54	23	26	212
Mean	17	27	61	52	87	165	411	387	183	26	9	10	120

Table 480 Modified Mean Discharges in CFS, Honey Creek near Plush, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1	0	0	
1929	1	1	2	1	0	11	12	29	9	1	0	0	6
1930	0	2	8	1	20	17	40	20	8	1	0	0	10
1931	2	2	3	3	4	8	15	4	1	0	0	0	4
1932	1	1	2	2	14	26	48	56	12	0	0	0	14
1933	1	1	1	1	3	4	17	39	23	1	0	0	8
1934	1	1	1	2	2	13	11	2	1	0	0	0	3
1935	0	2	2	2	2	7	68	65	19	1	0	0	14
1936	1	2	2	1	2	25	95	48	14	1	0	0	16
1937	0	0	0	0	0	9	59	51	16	1	0	0	11
1938	2	3	33	10	12	38	282	195	45	7	1	1	52
1939	2	3	1	1	1	42	34	13	6	0	0	0	9
1940	1	3	5	2	47	82	91	42	7	0	0	0	23
1941	2	4	2	2	16	43	50	69	37	3	1	1	19
1942	3	3	18	15	20	60	213	128	52	4	0	0	43
1943	1	3	4	5	15	129	183	115	93	11	1	0	47
1944	2	3	2	2	5	15	20	20	101	9	2	1	15
1945	4	8	8	13	20	18	83	122	47	5	1	1	28
1946	2	4	7	7	10	44	123	62	17	2	0	0	23
1947	2	5	7	5	11	17	42	22	17	1	0	1	11
1948	1	1	2	25	5	6	72	200	111	14	0	1	37
1949	2	4	2	1	3	21	167	90	23	2	0	0	26
1950	1	1	1	5	15	21	67	93	49	6	1	0	22
1951	2	7	24	11	50	48	140	98	23	2	0	0	34
1952	2	4	5	5	19	141	264	171	62	14	3	1	58
1953	2	2	2	43	26	34	72	121	89	16	2	1	34
1954	2	5	7	6	19	38	120	79	28	4	1	1	26
1955	2	5	4	4	5	7	13	90	25	6	0	0	13
1956	0	3	86	65	16	96	182	188	76	13	1	1	61
1957	5	10	10	3	71	69	83	133	36	4	1	0	35
1958	2	4	5	7	46	29	146	175	50	14	2	1	40
Mean	2	3	9	8	16	37	94	85	37	4	1	0	25

Table 481 Modified Mean Discharges in CFS, Chewaucan River near Paisley, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										26	19	20	
1929	28	33	40	30	23	95	104	200	89	26	16	20	59
1930	26	41	87	26	124	112	256	157	59	21	17	21	79
1931	26	21	10	24	36	57	99	65	20	9	6	13	32
1932	23	23	25	29	33	189	219	439	156	31	14	16	100
1933	23	28	17	24	27	43	140	218	299	38	16	18	74
1934	25	27	37	45	55	153	175	66	28	10	7	14	54
1935	25	36	32	32	42	75	317	451	156	37	16	17	103
1936	24	23	24	46	49	150	492	530	165	35	19	27	132
1937	26	21	26	26	26	57	267	343	139	42	19	22	84
1938	29	47	173	70	86	142	663	924	371	70	35	32	220
1939	41	49	45	38	39	168	275	135	45	18	12	19	74
1940	26	26	40	62	141	296	492	418	91	26	17	24	138
1941	32	33	39	44	67	126	165	398	149	39	33	35	97
1942	35	51	129	87	78	135	435	423	299	71	37	32	151
1943	33	67	87	107	104	374	782	625	446	105	42	36	234
1944	44	51	41	41	53	74	98	152	293	87	34	30	83
1945	36	51	57	67	120	70	232	566	263	55	28	28	131
1946	32	44	84	75	58	186	485	614	180	48	25	28	155
1947	36	45	42	39	78	94	216	214	99	27	17	21	77
1948	32	34	31	69	54	56	146	549	523	100	41	40	140
1949	43	46	26	31	39	105	414	501	145	41	25	27	120
1950	36	41	39	43	98	139	294	502	300	62	28	26	134
1951	52	86	188	86	209	208	695	562	193	44	28	30	198
1952	46	50	86	60	107	158	769	1129	575	144	53	44	268
1953	41	40	59	190	154	142	380	662	665	163	56	43	216
1954	46	69	64	56	130	269	662	719	222	67	40	41	199
1955	44	48	48	43	47	62	87	214	141	41	18	28	68
1956	34	55	464	366	141	290	826	1113	570	145	51	41	341
1957	63	65	92	38	185	295	357	658	269	56	34	37	179
1958	64	70	73	90	317	169	449	1050	328	85	47	43	232
Mean	36	44	74	66	91	150	366	487	243	56	27	28	139

Table 482 Modified Mean *Discharges in* CFS, Silver Creek near Silver Lake, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										16	9	2	
1929	3	2	2	2	4	5	3	8	6	4	1	1	3
1930	2	3	2	2	4	4	12	19	6	1	1	1	5
1931	1	2	2	1	1	3	3	5	1	0	0	0	2
1932	1	2	1	1	1	3	30	41	28	25	1	1	11
1933	2	2	1	1	1	3	6	32	32	13	2	1	8
1934	1	2	2	2	2	2	4	9	3	0	0	0	2
1935	1	2	2	2	2	2	17	33	36	18	2	1	10
1936	2	2	2	1	1	3	18	38	33	18	1	1	10
1937	1	1	2	2	2	2	14	42	24	14	2	0	9
1938	0	0	5	2	2	17	89	133	38	26	9	7	27
1939	5	3	3	3	3	9	25	31	20	6	1	1	9
1940	1	1	2	4	9	26	22	24	34	18	4	3	12
1941	2	2	3	4	3	10	20	35	29	15	5	2	11
1942	3	3	3	4	7	9	24	18	17	24	4	7	10
1943	5	3	6	13	10	52	282	109	32	33	5	10	47
1944	6	7	6	6	6	8	2	15	14	16	4	3	8
1945	3	3	5	6	10	4	2	14	15	23	5	9	8
1946	8	5	5	11	6	19	48	40	21	23	9	6	17
1947	3	3	5	4	5	4	5	21	16	14	4	6	8
1948	7	4	1	9	4	4	10	24	22	26	8	7	10
1949	9	2	4	4	4	8	28	31	34	32	7	4	14
1950	3	4	4	3	6	23	28	35	32	25	9	2	14
1951	5	8	42	27	50	53	200	115	38	29	16	15	50
1952	10	7	15	10	16	19	229	183	46	39	13	8	50
1953	7	6	6	28	39	35	76	140	72	44	23	15	41
1954	11	10	12	13	23	75	286	162	33	26	12	12	56
1955	13	12	8	8	10	10	6	16	30	26	8	3	12
1956	5	7	55	43	17	48	450	259	45	30	14	8	82
1957	5	5	4	4	34	114	92	113	30	22	8	12	37
1958	12	8	9	10	92	88	229	214	82	29	15	17	67
Mean	5	4	7	8	12	22	75	65	29	20	6	5	22

Table 483 Observed Mean Discharges in CFS, Silvies River near Burns, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										20	8	9	
1929	13	19	21	25	20	254	220	143	58	19	9	13	68
1930	15	20	38	30	99	76	43	27	9	4	3	3	31
1931	8	8	15	39	42	98	124	23	6	2	1	2	31
1932	4	5	10	10	20	255	844	398	76	7	3	2	136
1933	7	15	11	15	20	49	278	341	108	13	2	2	72
1934	7	15	27	40	41	30	12	6	2	0	0	1	15
1935	11	19	15	15	20	67	440	117	21	6	2	2	61
1936	5	9	10	15	20	73	728	208	40	5	5	7	94
1937	8	11	15	12	18	73	430	255	57	12	3	4	75
1938	9	29	101	86	113	481	1412	592	88	34	12	9	247
1939	13	29	28	39	45	457	539	79	17	4	4	6	105
1940	6	7	15	31	182	489	671	125	17	5	3	6	130
1941	11	31	52	58	89	861	769	436	176	39	29	33	215
1942	35	53	79	65	60	218	1367	540	225	52	14	13	227
1943	16	39	76	119	136	587	2182	673	228	59	20	12	346
1944	21	44	37	31	55	189	213	75	57	18	7	5	63
1945	8	17	40	137	329	202	605	658	310	40	12	9	197
1946	14	31	33	55	57	464	1056	418	116	43	12	13	193
1947	24	55	98	49	240	325	484	169	106	23	7	7	132
1948	16	30	43	63	159	144	604	1019	446	84	27	19	221
1949	33	44	41	26	111	397	782	432	74	11	7	7	164
1950	15	30	31	27	37	238	764	427	151	34	12	6	148
1951	20	40	72	66	254	425	1328	463	94	35	11	10	235
1952	19	30	48	44	51	376	2716	947	168	59	22	17	375
1953	20	26	33	127	243	298	861	831	473	78	26	21	253
1954	29	51	71	64	191	352	536	197	92	18	9	10	135
1955	18	28	25	23	31	52	193	372	88	25	6	7	72
1956	13	30	113	125	103	593	1467	774	208	45	15	16	292
1957	33	52	66	41	649	546	944	655	142	24	11	11	264
1958	32	35	51	55	529	468	1394	1028	218	63	26	23	327
Mean	16	28	44	51	132	305	800	414	129	27	10	9	164

Table 484 Observed Mean Discharges in CFS, Donner und Blitzen River near Frenchglen, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										66	33	33	
1929	55	59	63	60	73	94	130	279	130	49	45	43	90
1930	48	52	69	66	79	108	181	194	146	46	33	36	88
1931	48	57	60	57	67	86	77	87	55	30	15	15	54
1932	77	89	85	87	100	129	238	450	271	102	43	34	142
1933	57	63	55	70	57	71	114	203	218	57	39	31	86
1934	46	58	56	54	63	76	104	59	39	25	6	6	49
1935	34	44	46	46	48	62	233	380	293	96	36	28	112
1936	51	66	64	68	58	62	196	238	142	44	31	49	89
1937	52	54	48	52	60	70	112	299	162	62	26	31	86
1938	45	52	74	40	70	169	397	455	281	89	44	40	146
1939	43	51	49	42	42	232	250	227	110	46	30	29	96
1940	34	32	33	40	72	159	255	376	148	43	30	37	105
1941	42	57	44	42	145	111	129	403	243	84	46	43	116
1942	45	61	51	77	74	156	373	463	424	128	53	48	163
1943	47	56	123	98	150	200	305	315	364	160	62	47	161
1944	49	52	45	44	46	83	126	243	228	87	39	36	90
1945	38	42	47	63	91	113	352	558	420	138	57	46	164
1946	47	50	63	50	64	99	218	283	184	80	42	37	101
1947	42	51	52	44	61	68	143	251	141	46	31	30	80
1948	35	40	39	83	39	92	162	515	480	104	45	40	140
1949	42	41	39	34	49	95	208	285	147	51	35	33	88
1950	37	38	33	32	42	107	160	318	290	97	43	36	103
1951	39	45	59	54	177	149	278	301	238	73	43	39	125
1952	47	44	42	42	43	157	666	610	433	196	74	56	201
1953	49	47	48	53	59	63	115	284	502	176	59	46	125
1954	45	46	62	56	93	150	184	256	160	66	41	38	100
1955	36	37	36	38	35	72	123	329	312	73	37	35	97
1956	38	44	138	175	63	155	281	456	278	97	46	41	151
1957	64	63	91	42	204	197	214	578	435	109	51	46	174
1958	59	52	51	61	283	85	206	538	272	102	55	47	151
Mean	46	51	59	59	84	116	218	341	252	84	40	37	116

Table 475. Observed Mean Discharges in CFS, Trout Creek near Denio, Nevada

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										6	3	2	
1929	4	5	5	5	6	10	16	46	17	3	2	3	10
1930	5	6	6	6	7	12	16	25	7	1	1	1	8
1931	3	4	4	4	5	9	7	8	4	1	0	0	4
1932	7	8	8	8	10	17	44	116	49	10	2	2	23
1933	4	5	4	6	4	6	13	32	30	4	2	2	9
1934	3	4	4	4	5	7	11	4	3	1	0	0	4
1935	2	3	3	3	3	5	43	92	60	10	2	1	19
1936	3	6	5	6	5	5	31	40	19	3	2	3	11
1937	4	6	3	4	5	6	13	59	23	5	1	2	11
1938	3	4	7	5	8	16	68	142	50	14	4	3	27
1939	7	8	7	6	6	17	27	20	5	2	1	1	9
1940	3	3	3	5	6	15	38	55	11	3	1	3	12
1941	4	9	7	6	12	20	25	68	23	6	3	3	16
1942	5	6	5	5	6	9	43	91	69	11	4	4	22
1943	5	7	8	9	15	27	73	47	44	14	4	4	21
1944	6	7	4	5	6	7	18	56	31	11	4	3	13
1945	6	7	6	6	11	13	40	109	65	15	6	4	24
1946	7	9	8	9	9	17	51	43	14	6	4	4	15
1947	6	7	7	6	6	5	17	23	16	4	1	2	8
1948	5	6	6	6	6	6	20	55	46	11	4	3	14
1949	6	7	6	3	4	7	26	38	13	4	1	1	10
1950	4	5	5	5	5	6	21	44	22	6	3	3	11
1951	4	5	7	6	10	15	47	59	18	5	3	3	15
1952	4	5	5	5	5	17	105	151	92	41	9	7	37
1953	6	6	6	8	7	11	25	48	88	15	5	4	19
1954	6	7	7	7	7	10	19	21	9	4	3	3	9
1955	4	5	5	5	5	5	9	30	21	4	2	2	8
1956	3	4	6	13	6	15	38	63	27	10	3	3	16
1957	5	8	8	5	9	24	47	115	43	10	4	4	24
1958	6	6	6	5	21	15	45	93	52	15	6	5	23
Mean	5	6	6	6	7	12	33	60	32	8	3	3	15

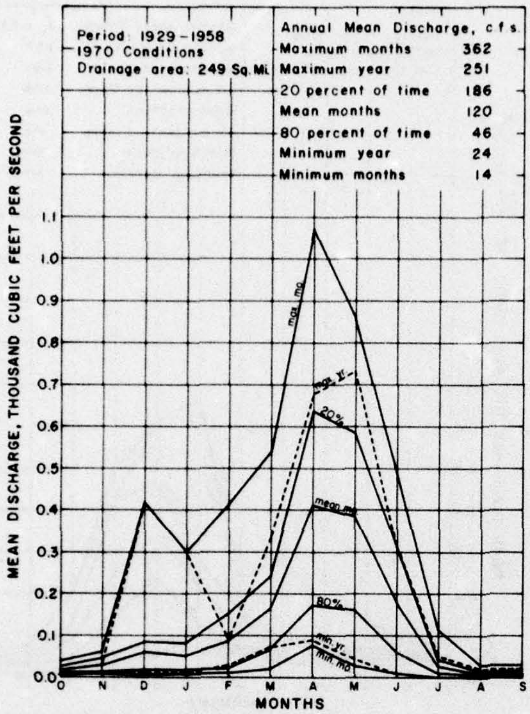


Figure 864 Monthly discharge, Deep Creek above Adel, Oregon

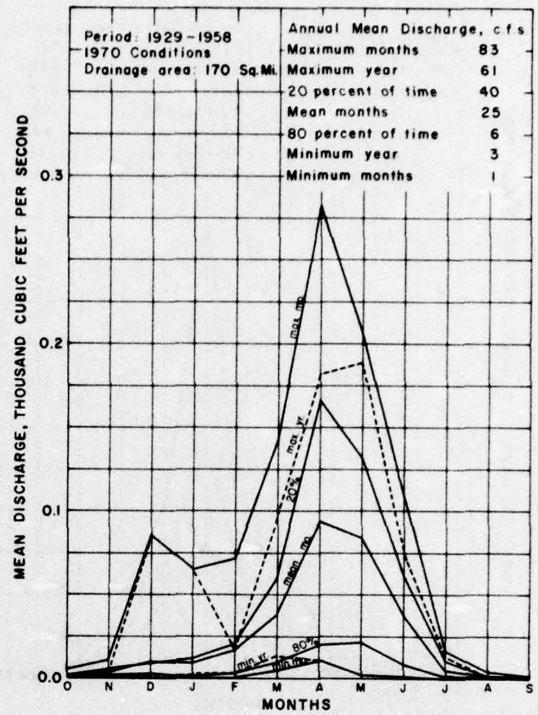


Figure 865 Monthly discharge, Honey Creek near Plush, Oregon

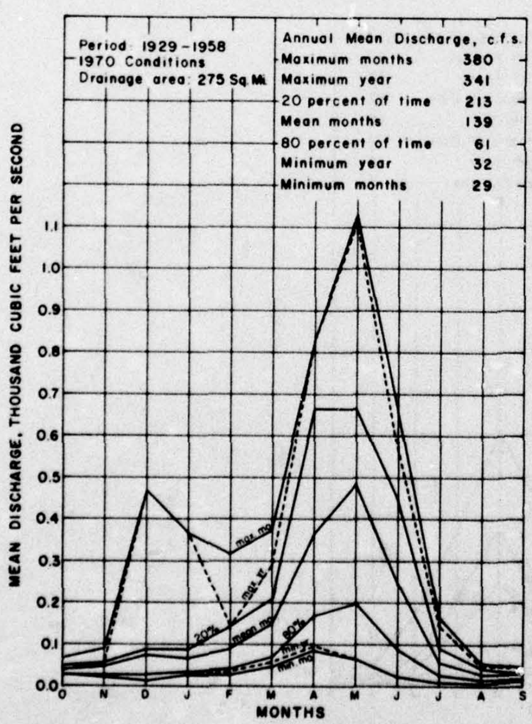


Figure 866 Monthly discharge, Chewaucan River near Paisley, Oregon

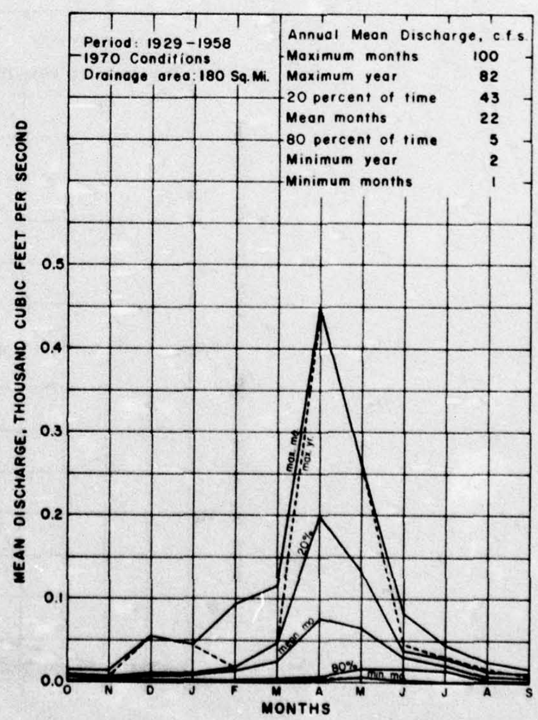


Figure 867 Monthly discharge, Silver Creek near Silver Lake, Oregon

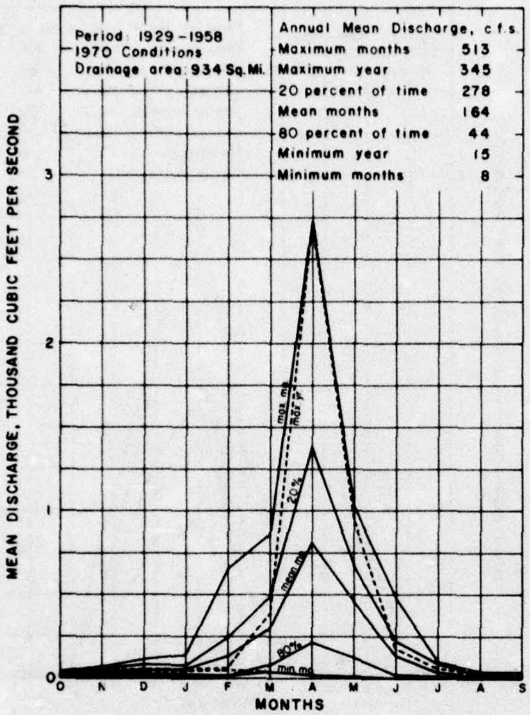


Figure 868 Monthly discharge, Silvies River near Burns, Oregon

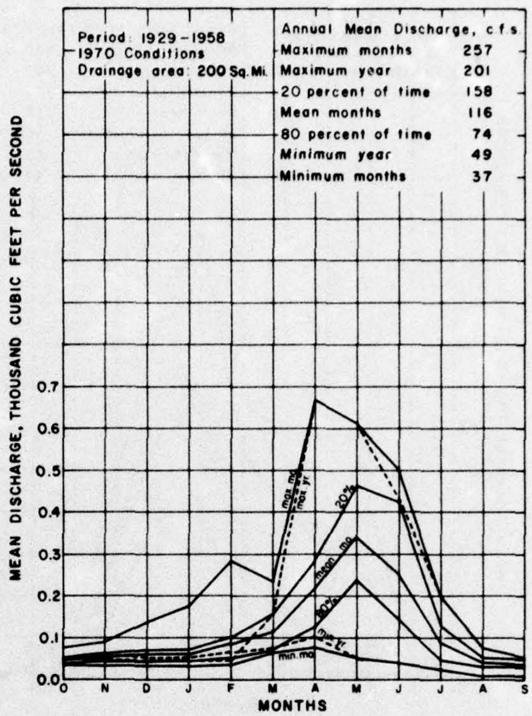


Figure 869 Monthly discharge, Donner und Blitzen River near Frenchglen, Oregon

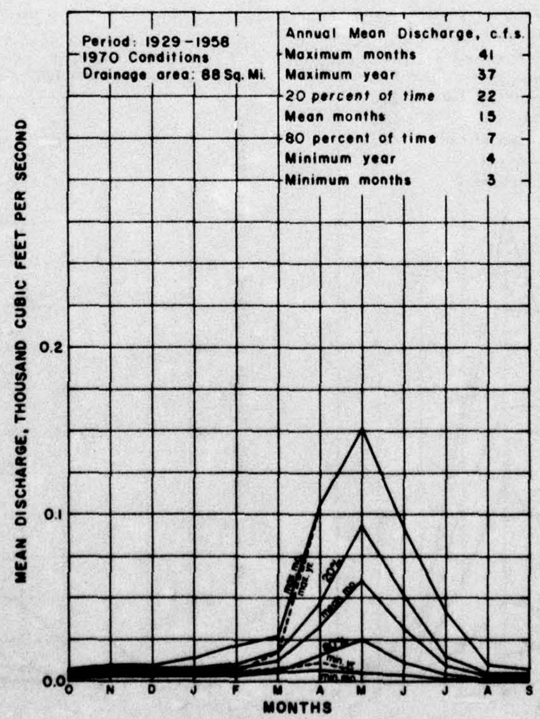


Figure 870 Monthly discharge, Trout Creek near Denio, Nevada

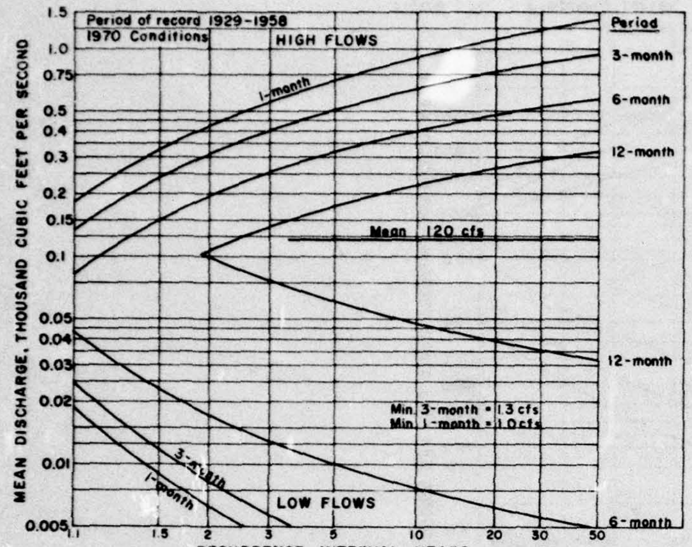


Figure 871 Frequency curves, Deep Creek ab. Adel, Oregon

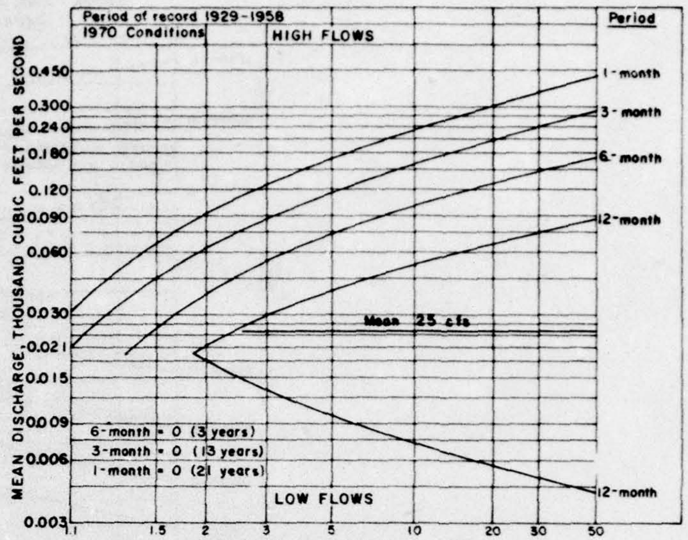


Figure 872 Frequency curves, Honey Creek near Plush, Oregon

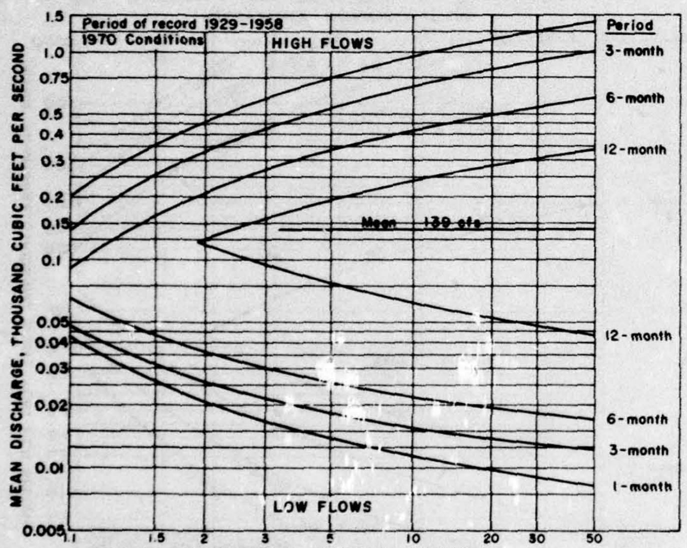


Figure 873 Frequency curves, Chewaucan River near Paisley, Oregon

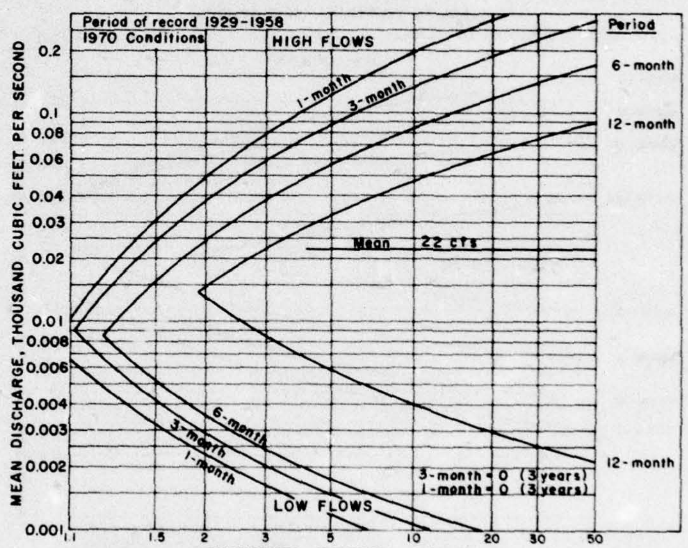


Figure 874 Frequency curves, Silver Creek near Silver Lake, Oregon

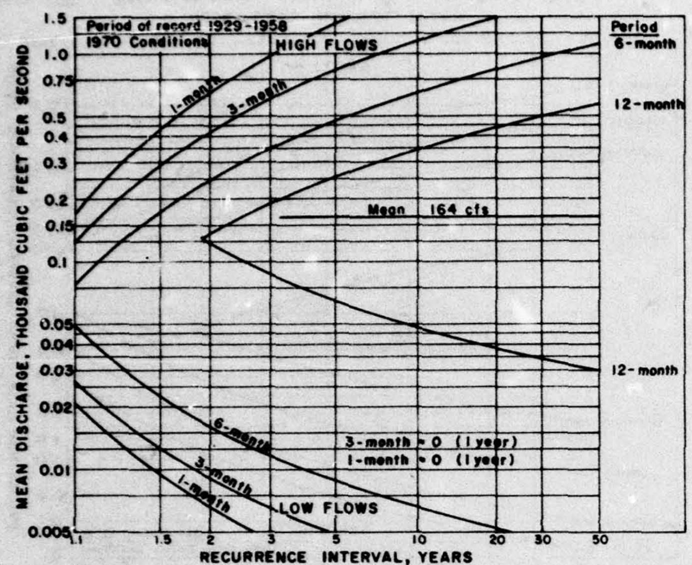


Figure 875 Frequency curves, Silvies River near Burns, Oregon

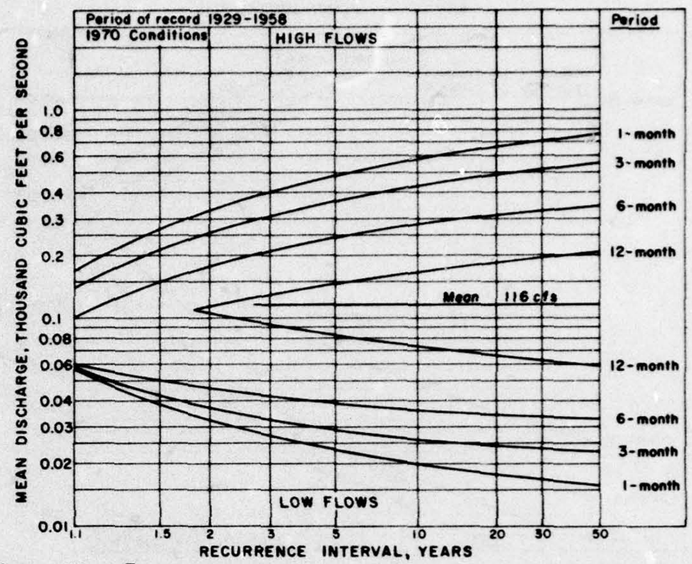


Figure 876 Frequency curves, Donner und Blitzen River near Frenchglen, Oregon

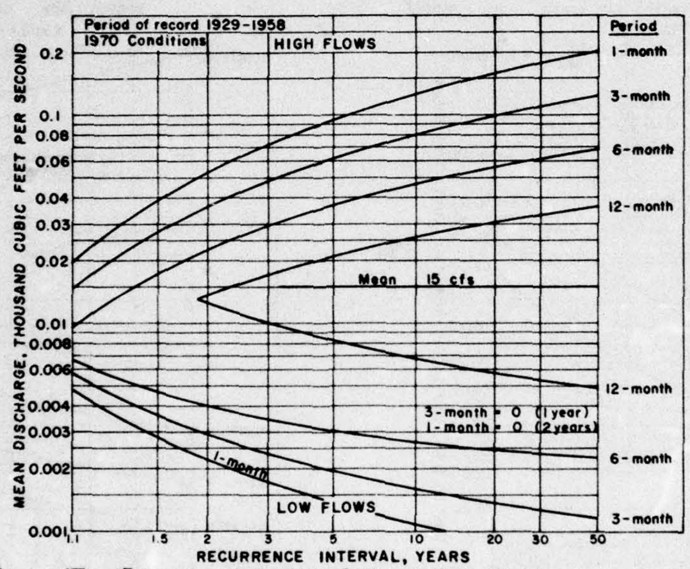


Figure 877 Frequency curves, Trout Creek near Denio, Nevada

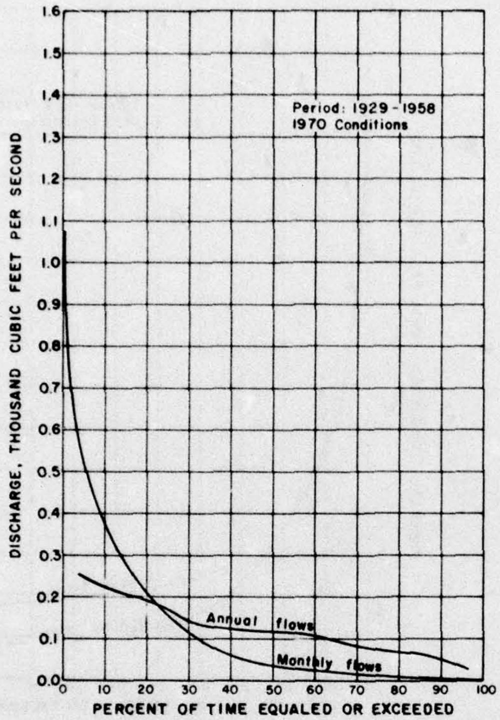


Figure 878 Duration curves, Deep Creek ab. Adel, Oregon

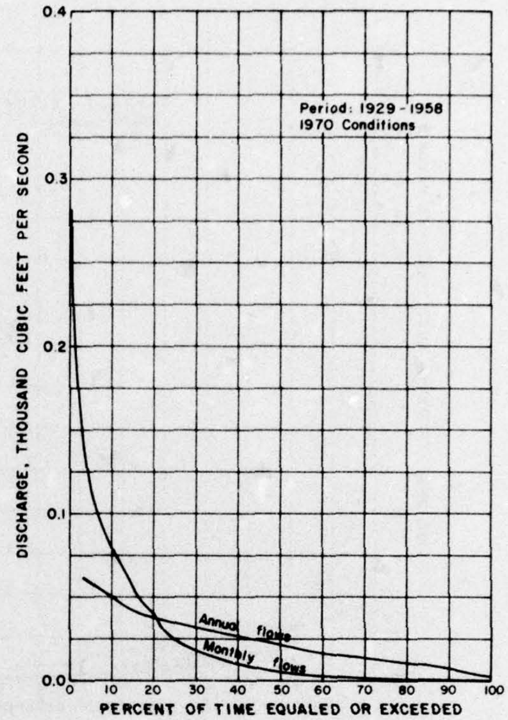


Figure 879 Duration curves, Honey Creek near Plush, Oregon

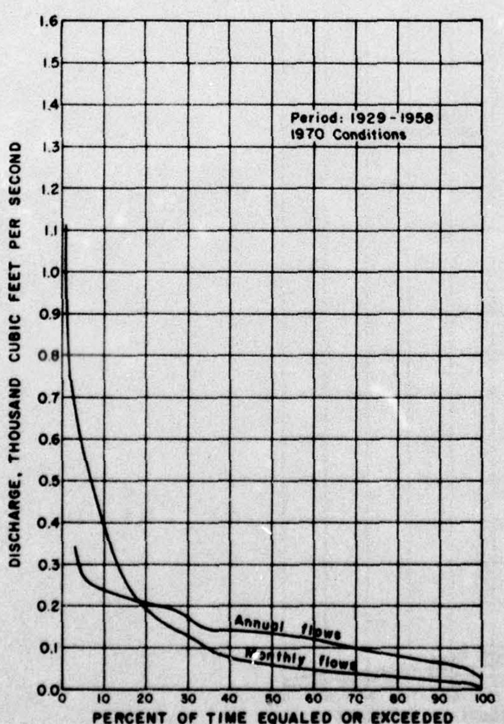


Figure 880 Duration curves, Chewaucan River near Paisley, Oregon

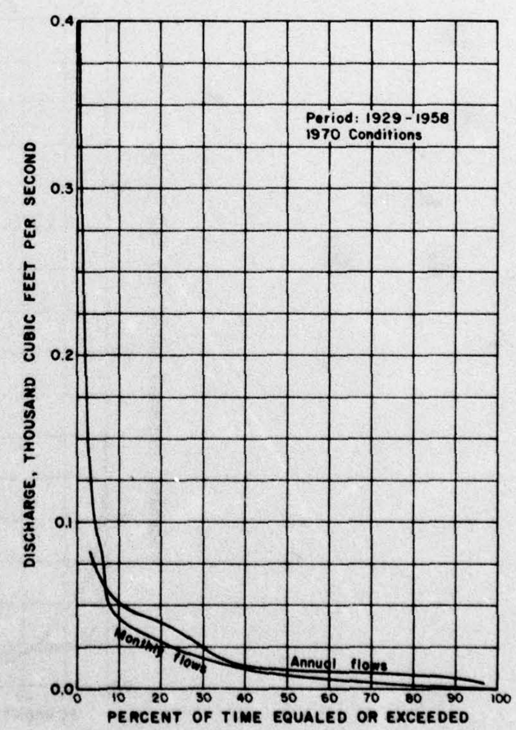


Figure 881 Duration curves, Silver Creek near Silver Lake, Oregon

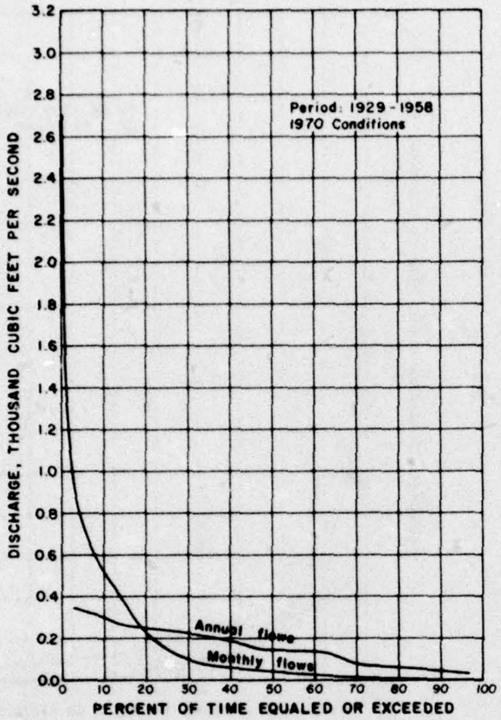


Figure 882 Duration curves, Silvies River near Burns, Oregon

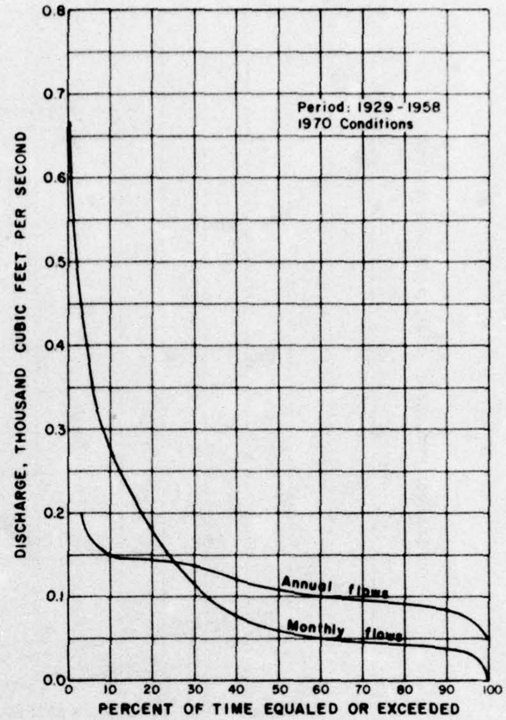


Figure 883 Duration curves, Donner und Blitzen River near Frenchglen, Oregon

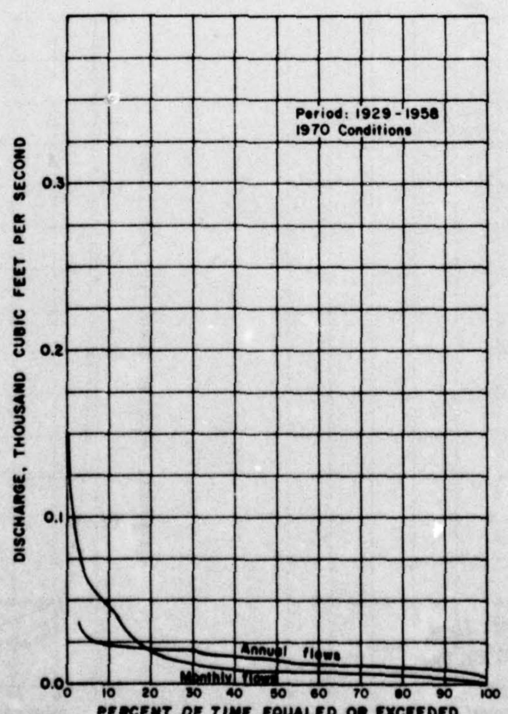


Figure 884 Duration curves, Trout Creek near Denio, Nevada

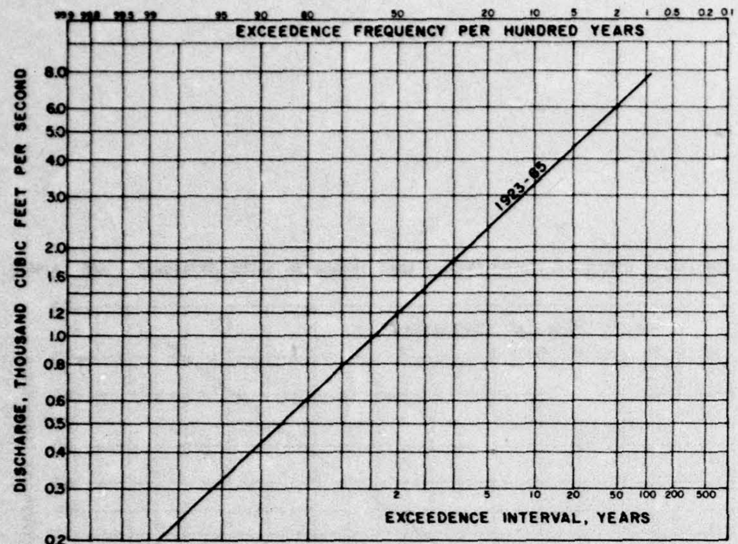


Figure 885 Frequency curve of annual peak flows, Deep Creek ab. Adel, Oregon

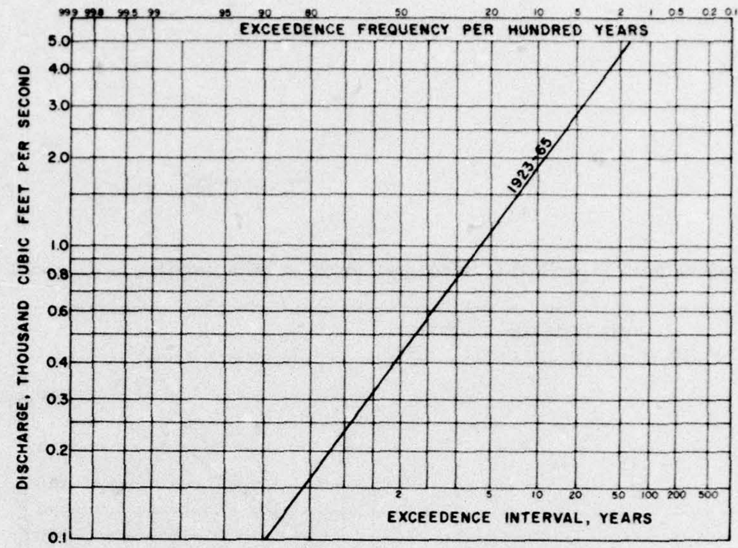


Figure 886 Frequency curve of annual peak flows, Honey Creek near Plush, Oregon

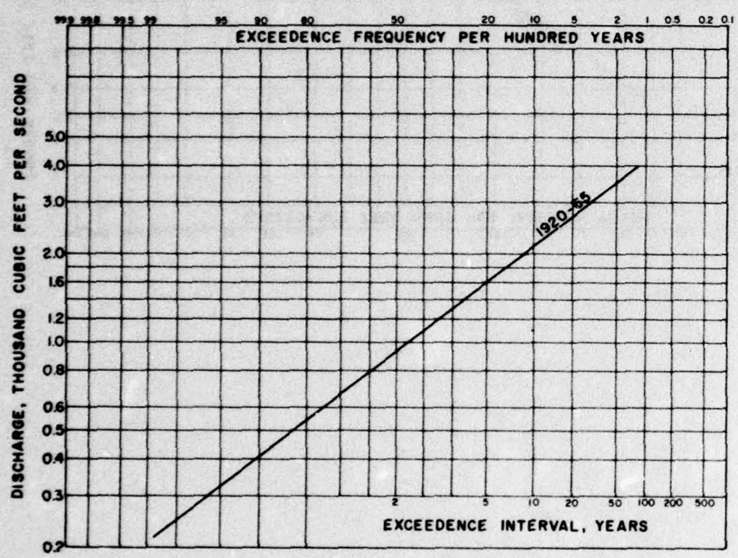


Figure 887 Frequency curve of annual peak flows, Chewaucan River nr. Paisley, Ore.

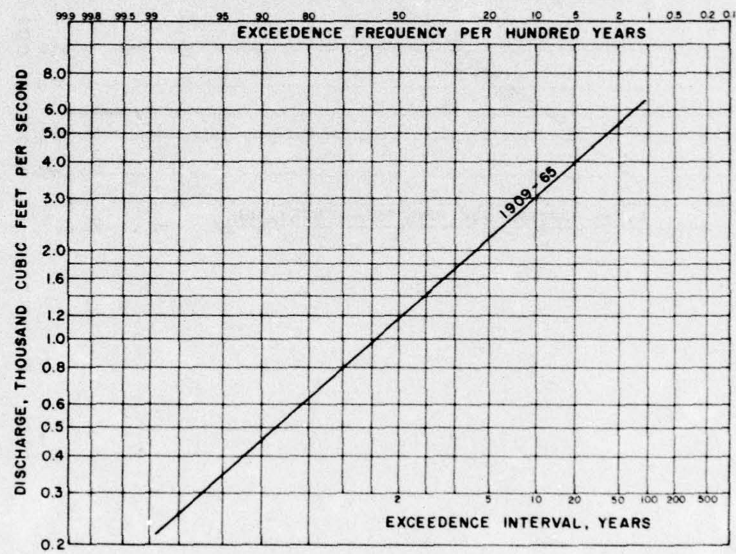


Figure 888 Frequency curve of annual peak flows, Silvies River near Burns, Oregon

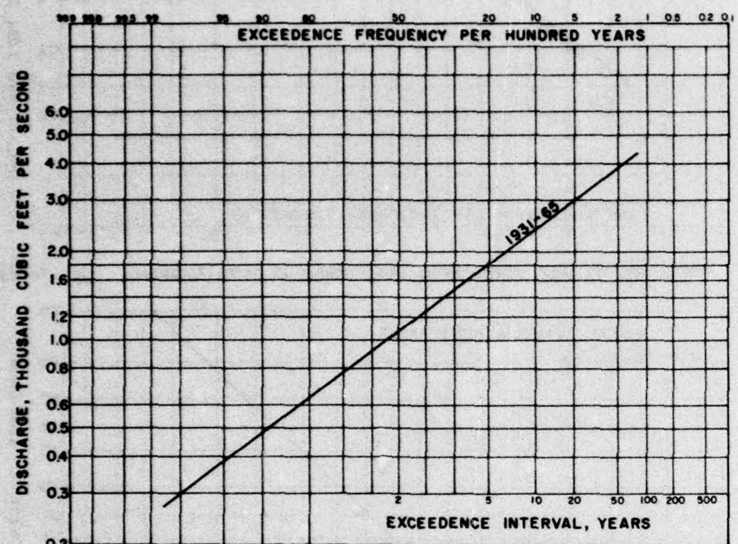


Figure 889 Frequency curve of annual peak flows, Donner und Blitzen R. nr. Frenchglen

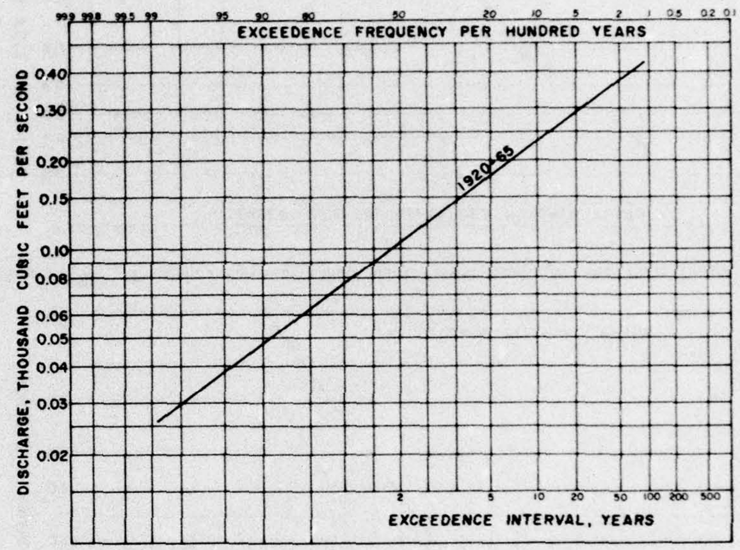


Figure 890 Frequency curve of annual peak flows, Trout Creek nr. Denio, Nevada

Table 486 - Dependable Yield, Deep Creek above Adel, Oreg.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	24	20.0
2	1933-1934	37	30.8
3	1929-1931	42	35.0
4	1931-1934	48	40.0
5	1930-1934	51	42.5
6	1929-1934	49	40.8
7	1929-1935	59	49.2
8	1929-1936	66	55.0
9	1929-1937	67	55.8
10	1929-1938	80	66.6
30	1929-1958	120	100.0

Table 487 - Dependable Yield, Honey Creek near Plush, Oreg.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	3	12.0
2	1933-1934	5	20.0
3	1929-1931	6	24.0
4	1931-1934	7	28.0
5	1930-1934	7	28.0
6	1929-1934	7	28.0
7	1929-1935	8	32.0
8	1929-1936	9	36.0
9	1929-1937	9	36.0
10	1929-1938	14	56.0
30	1929-1958	25	100.0

Table 488 - Dependable Yield, Chewaucan River near Paisley, Oreg.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	32	23.0
2	1930-1931	56	40.3
3	1929-1931	57	41.0
4	1931-1934	65	46.8
5	1930-1934	68	48.9
6	1929-1934	66	47.5
7	1929-1935	71	51.1
8	1929-1936	79	56.8
9	1929-1937	80	57.6
10	1929-1938	94	67.6
30	1929-1958	139	100.0

Table 489 - Dependable Yield, Silver Creek near Silver Lake, Oreg.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	2	9.1
2	1930-1931	3	13.6
3	1929-1931	3	13.6
4	1929-1932	5	22.7
5	1930-1934	6	27.3
6	1929-1934	5	22.7
7	1929-1935	6	27.3
8	1929-1936	6	27.3
9	1929-1937	7	31.8
10	1929-1938	9	40.9
30	1929-1958	22	100.0

Table 490 - Dependable Yield, Silvies River near Burns, Ore.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	15	9.1
2	1930-1931	31	18.9
3	1929-1931	43	26.2
4	1933-1936	60	36.6
5	1930-1934	57	34.8
6	1930-1935	58	35.4
7	1929-1935	59	36.0
8	1929-1936	63	38.4
9	1929-1937	65	39.6
10	1929-1938	83	50.6
30	1929-1958	164	100.0

Table 491 - Dependable Yield, Donner und Blitizen R. near Frenchglen, Ore.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	49	42.2
2	1933-1934	68	58.6
3	1929-1931	78	67.2
4	1931-1934	83	71.6
5	1930-1934	84	72.4
6	1929-1934	85	73.3
7	1931-1937	88	75.9
8	1930-1937	88	75.9
9	1929-1937	89	76.7
10	1929-1938	94	81.0
30	1929-1958	116	100.0

Table 492 - Dependable Yield, Trout Creek near Denio, Nev.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	4	26.7
2	1930-1931	6	40.0
3	1929-1931	7	46.7
4	1931-1934	10	66.7
5	1930-1934	10	66.7
6	1929-1934	10	66.7
7	1929-1935	11	73.3
8	1929-1936	11	73.3
9	1929-1937	11	73.3
10	1930-1939	12	80.0
30	1929-1958	15	100.0

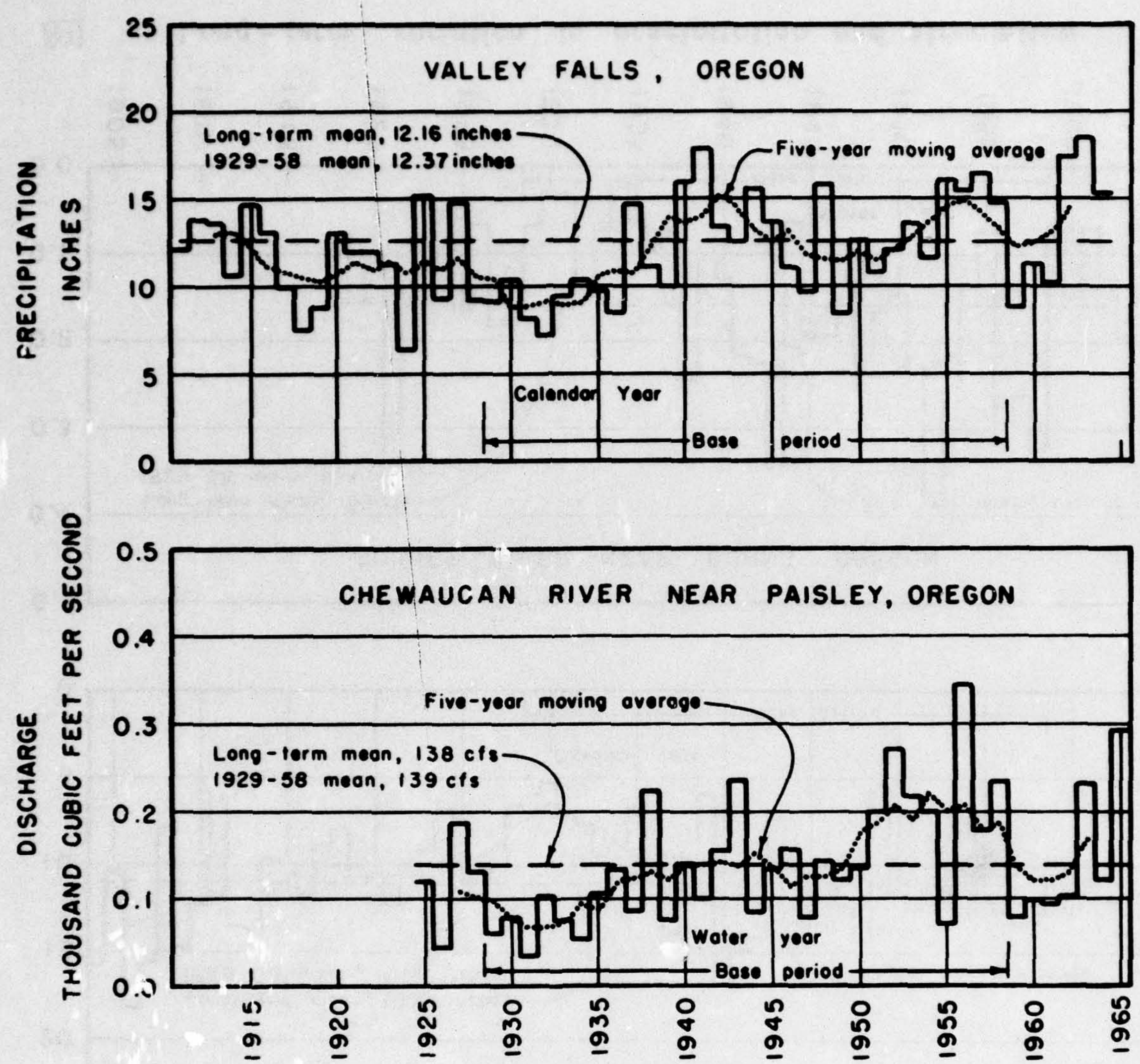


Figure 892 Long-term variation in precipitation and streamflow.

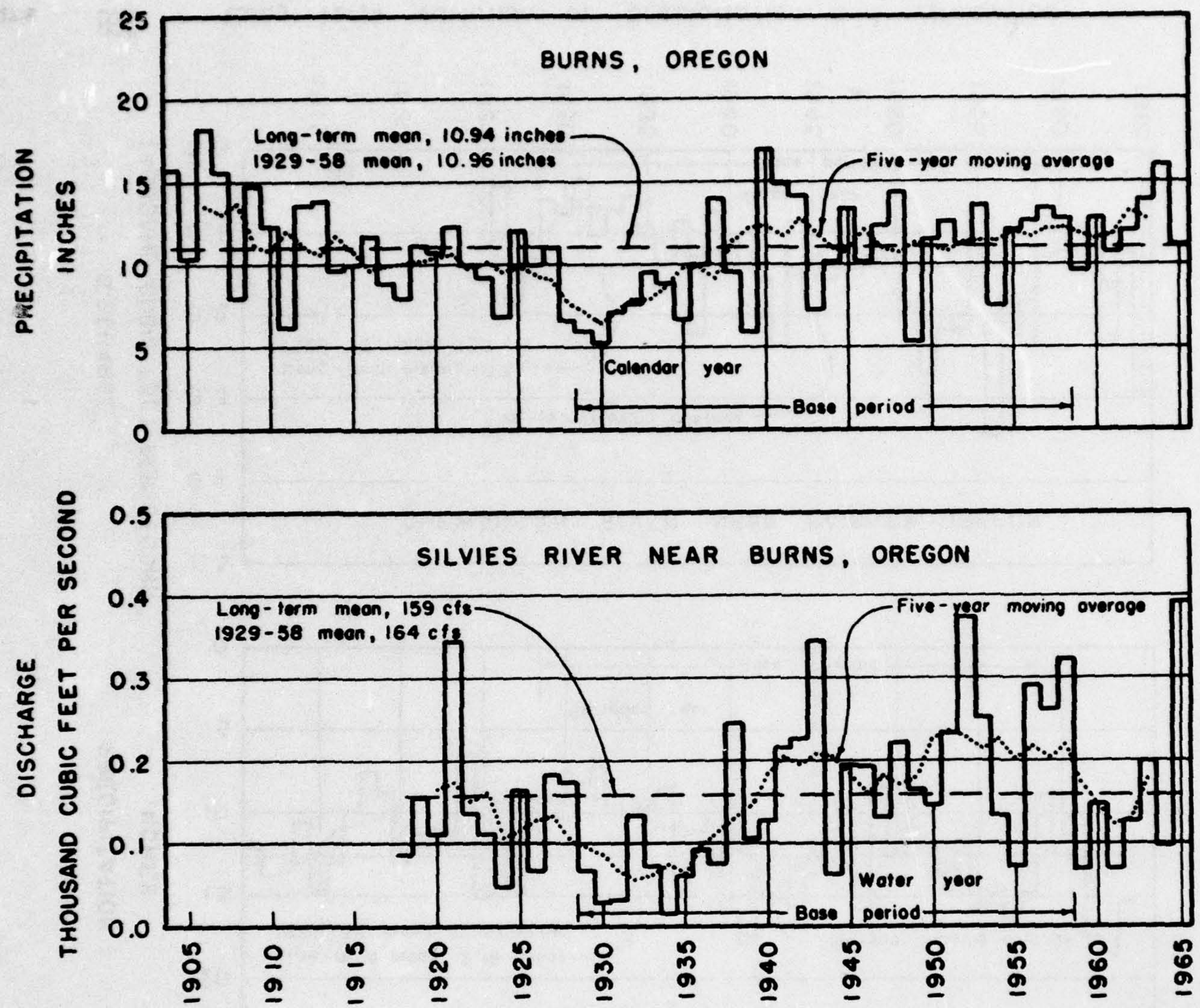


Figure 891 Long-term variation in precipitation and streamflow

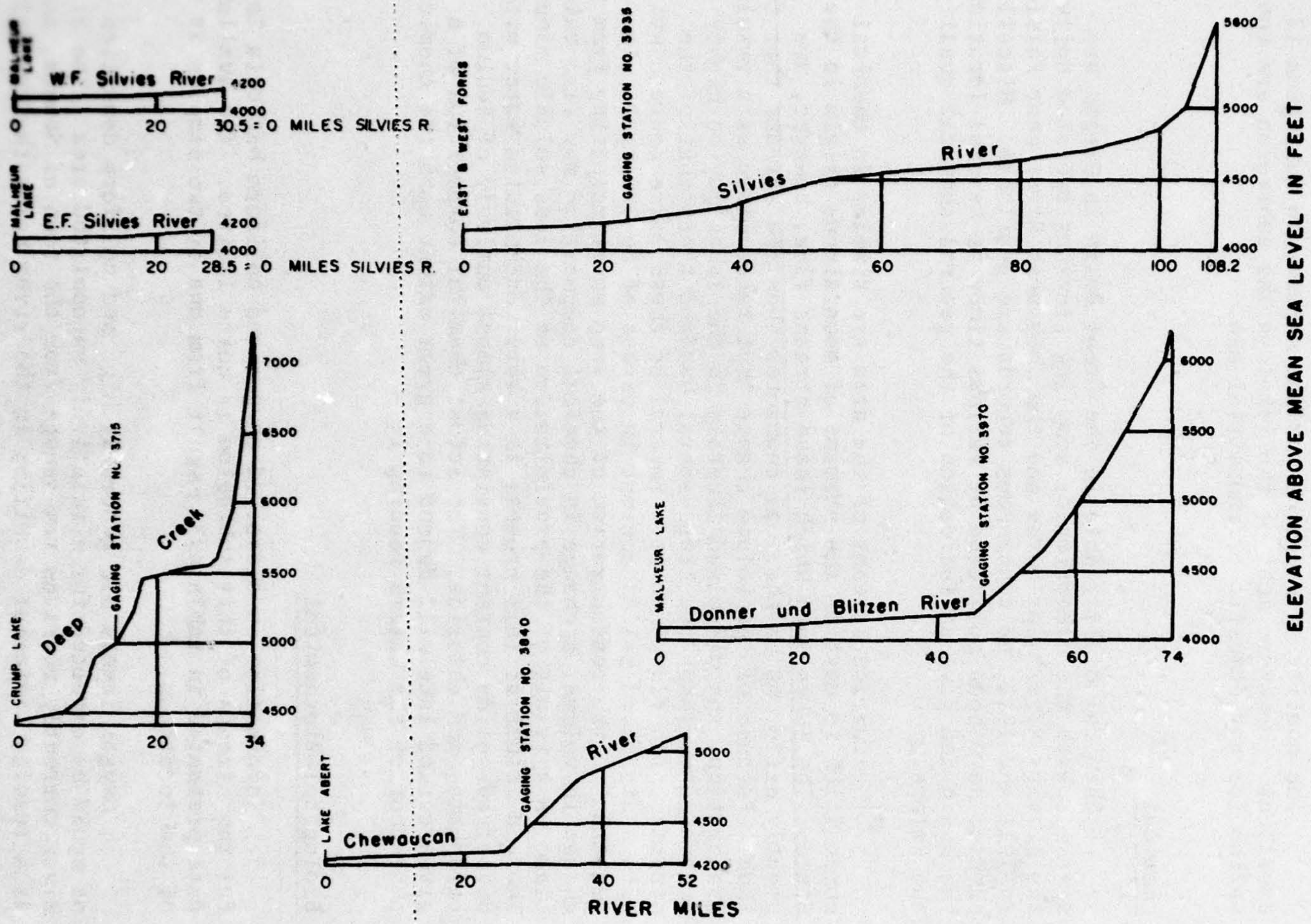


Figure 893. Profiles of principal streams, Subregion 12.

Quality

The quality of water of surface streams in Subregion 12 is excellent. However, most of the lakes in the subregion are too saline for any domestic or industrial use.

Chemical

Chemical-quality data in the Great Basin in Oregon are sparse. With the exception of sampling stations operated daily on the Silvies River near Burns and the Chewaucan River near Paisley in 1911 and 1912, no continuous records are available. Miscellaneous samples have been collected at various times at several locations in the basin and give an indication of the general chemical quality of the waters.

The surface streams of the area are similar in chemical composition to most of the streams of mountainous origin in the State. The lakes into which these streams flow, however, are greatly different in chemical character than the streams that feed them. Because of the volume change that takes place as a result of evaporation, the dissolved minerals in the lakes may be highly concentrated, perhaps reaching several hundred times that of the streams which flow into it. Several of these lakes contain water with a dissolved-solids content in excess of 30,000 mg/l. In addition to the concentration of the lake water resulting from this change in volume, a change in chemical composition may also take place as a result of the precipitation of the less soluble minerals. The end result of this process is a very concentrated water with a dissolved-solids content consisting almost entirely of sodium, carbonate, and chloride. The actual chemical composition of a given closed lake will depend to a great extent upon the chemical character of the waters feeding it.

Biological-Biochemical

Information on dissolved oxygen and coliform bacteria levels for the streams of this subregion is quite limited. The available data presented in table 493 result from one or two samples at many of the locations.

Oxygen levels are generally high and coliform densities low, as would be expected for a relatively unpopulated area. The Silvies River currently receives raw sewage from the town of Seneca, and, as a result, bacterial densities in the river below the community are undesirable.

Table 493 - Dissolved Oxygen & Coliform Organisms Densities
Oregon Closed Basin Subregion

Location	Dissolved Oxygen mg/1 Mean	Min	Max	Coliform Organisms per 100 ml Mean	Min	Max
Donner und Blitzen R.nr French Glen	7.0	6.7	10.9	54	46	94
Silvies R. above Seneca	8.9	7.0	11.1	684	45	2,400
Silvies R. below Seneca	9.1	7.7	10.7	6,863	450	13,000
Silvies R. nr Burns	8.2	6.0	10.3	947	167	2,400
Chewaucan R. above Mill	-	9.8	10.1	-	60	62
Chewaucan R. near Paisley	-	9.8	11.0	-	60	600
Chewaucan R. at Hwy 31	-	10.0	10.5	-	60	620
Silver Creek at Hwy 31	9.3	-	-	60	-	-
Ana Springs Reservoir	10.5	-	-	4.5	-	-
Lake Abert	5.7	-	-	4.5	-	-
Honey Creek at Plush	11.5	-	-	50	-	-
Hart Lake at Plush	8.9	-	-	700	-	-
Crooked Creek nr Valley Falls	8.4	-	-	2,400	-	-

Note: Values reported are based on four or less samples.

The one value obtained for dissolved-oxygen concentrations in Lake Abert is less than saturation. However, considering the high chloride content of the lake (10,000 mg/1) and no appreciable coliform count, no sanitary problem appears to exist.

Sediment

The only suspended sediment concentrations measured in the subregion were on Chewaucan and Silvies Rivers in 1911 and 1912. (17) Sediment yield is known to be small and is believed to be less than 0.1 acre-foot per square mile per year.

Water Temperature

Representative information on water temperature of streams is not available.

GROUND WATER

Subregion 12 is underlain largely by alluvial deposits and volcanic and sedimentary rocks of Miocene or younger age that are capable of yielding moderate to large supplies at many places. Permeable aquifers are perhaps more widespread than in any other subregion. However, the availability of ground water is limited by the depth to the water, which is more than 500 feet over considerable areas, and is more than 1,000 feet at some places. Also, the area is semiarid to arid so that annual recharge is small in comparison with most other subregions. Water quality is generally

not quite so good as in other subregions; however, dissolved solids commonly are less than 1,000 mg/l. Excessive sodium, boron, and fluoride cause problems at places. Ground-water temperatures generally range from about 47° to 55°F., but some wells yield warm to hot water. Subregion 12 contains the greatest concentration of thermal springs of any part of Oregon. (193-38 to 41 and figure 6)

Aquifer Units and Their Hydrologic Characteristics

Six aquifer units have been delineated in Subregion 12 and are shown on the map, figure 894. Only a small part of the subregion is included on the Geologic Map of Oregon. (202) That map and various other maps, made over a period of many years, were used in compiling the aquifer unit map. Because of differences between those maps, an aquifer unit in one area may include slightly different combinations of formations than in another area.

The youngest aquifer units are the alluvial deposits (QTal) and the volcanic rocks (QTv), both of Quaternary and late Pliocene age. The alluvial deposits consist of unconsolidated gravel, sand, silt, and clay of fluvial and lacustrine origin. They occur as valley and basin fill and, because they underlie low-lying areas, they generally are saturated. They are good aquifers where they are coarse grained and extend a few tens of feet or more below the water table. Yields commonly range from a few hundred to more than 1,000 gpm, and specific capacities from 5 to 100 gpm per foot. Where the deposits are thin or consist only of very fine sand or silt, they yield little water. The younger volcanic rocks (QTv) consist of basaltic and andesitic flows, usually open-textured and vesicular or scoriacious. Breccia, agglomerate, scoria, cinders, and ash occur as interbeds. These rocks form domes and cones and are widespread in the western part of the subregion. They are the most permeable rocks in the subregion and yield large to very large quantities of water where several tens of feet of the aquifer unit are saturated. Specific capacities of the better wells range up to 1,000 gpm per foot. However, at some places the rocks are above the zone of saturation or only the bottom few feet are saturated.

Sedimentary strata (Ts) and volcanic rocks (Tb), both of Miocene-Pliocene age, occur widely in Subregion 12 and contain important aquifers. Both aquifer units include many formations and these range widely in their hydrologic characteristics. The sedimentary strata include tuffaceous siltstone and sandstone, ash, pumice, scoria, sandstone, and conglomerate. Locally they include incoherent or lightly cemented sand and gravel. Wells in

EXPLANATION

QTal

Valley and basin fill deposits of Quaternary and Pliocene age.

Where saturated, clean, coarse-grained deposits yield moderate to large supplies. Fine-grained deposits yield small supplies.

Quality variable. Dissolved solids mostly <500 mg/l, exceed 1000 in some places. Sodium, boron may be excessive.

Volcanic rocks of Quaternary-late Tertiary age.

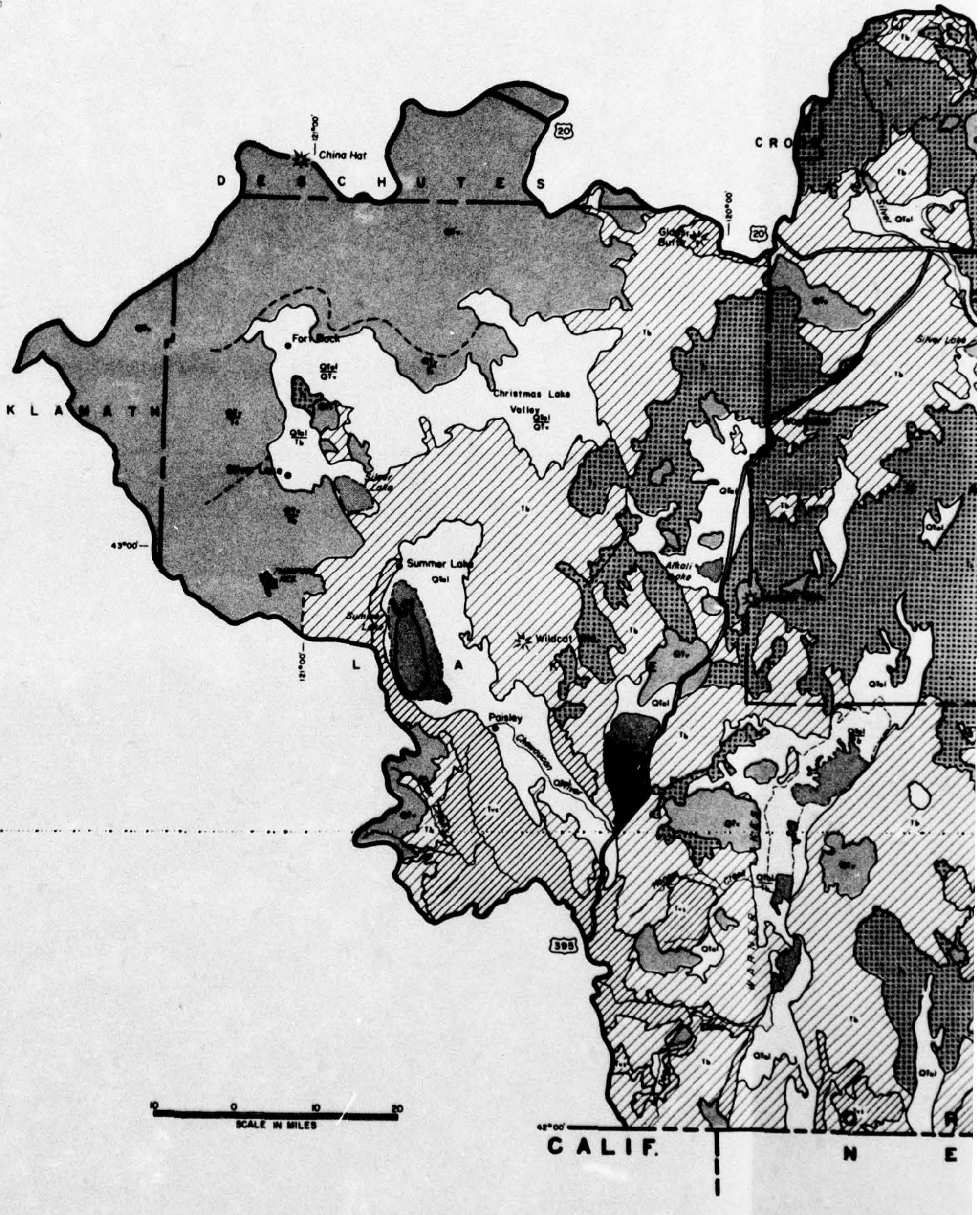
Yields large supplies where saturated. Are above zone of saturation in much of area.

Few data. Dissolved solids probably <500 mg/l. Sodium and boron may be excessive in some wells.

Tuffaceous sedimentary deposits and interbedded flows and pyroclastics of Tertiary age.

Widely varying yields--from small to large.

Dissolved solids generally <1000 mg/l; may be highly mineralized in some places. Some sodium, boron hazard.



Tvs

Silicic volcanic rocks and interbedded sediments of Tertiary age.

Generally small to moderate yields; moderately large at a few places.

Dissolved solids probably generally <1000 mg/l. Higher in some areas.

pT

Metamorphic, sedimentary, and granitic rocks of pre-Tertiary age.

Probably yields only small supplies.

Quality probably ranges from excellent to highly saline.

Tuffaceous sedimentary deposits and interbedded flows and pyroclastics of Tertiary age.

Widely varying yields--from small to large.

Dissolved solids generally <1000 mg/l; may be highly mineralized in some places. Some sodium, boron hazard.

Basalt and andesite flows and flow breccia of Tertiary age.

Thick sequences generally yield moderate to large supplies where saturated. Individual flows only small supplies.

Quality ranges widely but dissolved solids generally <1000 mg/l. Excessive sodium, boron at some places.

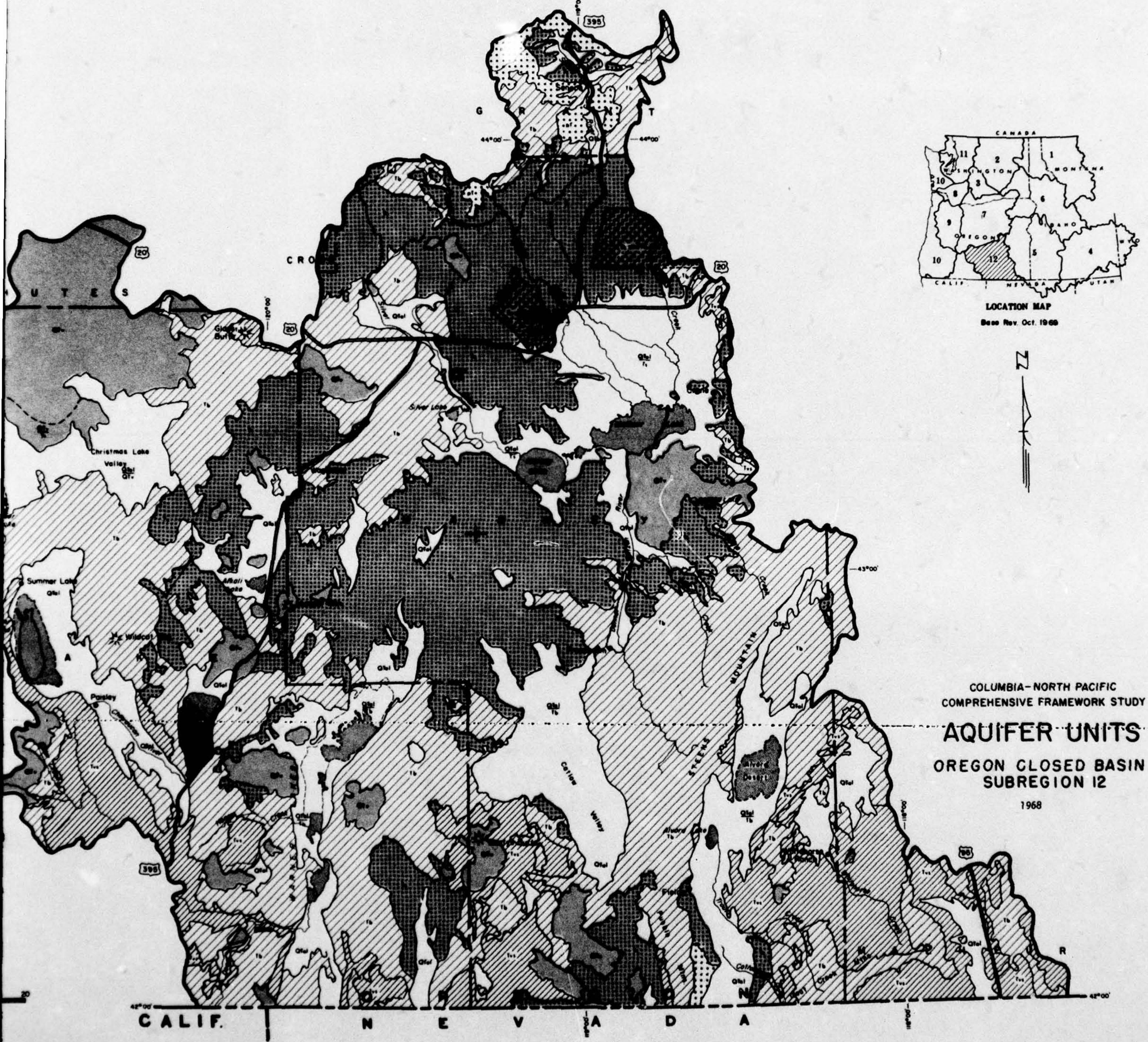
Tb

Basalt and andesite flows and flow breccia of Tertiary age.

Thick sequences generally yield moderate to large supplies where saturated. Individual flows only small supplies.

Quality ranges widely but dissolved solids generally <1000 mg/l Excessive sodium, boron at some places.

Where a surficial aquifer overlies one or more aquifers that also furnish significant amounts of water as, for example, where Quaternary alluvial deposits overlie Tertiary sedimentary rocks, the relation is indicated by the map symbols, $\frac{Qal}{Ts}$.



COLUMBIA–NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

AQUIFER UNITS

OREGON CLOSED BASIN
SUBREGION 12

1968

FIGURE 894

2

the coarser grained, less consolidated deposits have moderate to moderately large yields. The volcanic rocks are chiefly basaltic, but include andesitic, dacitic, and rhyodacitic flows and interbedded pyroclastic and tuffaceous sedimentary rocks; the younger flows are more porous and permeable. Generally, where several hundred feet of saturated material are penetrated, one or more aquifers are encountered, and moderately large to large yields can be obtained. The two units crop out in more than half the subregion (table 495). They also underlie much of the alluvial deposits (QTal) and the younger volcanic rocks (QTv) and are important aquifers where the younger rocks are thin or are mostly above the zone of saturation. Thus, the sedimentary strata (Ts) and volcanic rocks (Tv) contain important aquifers in about 75 to 80 percent of the area.

The older volcanic and sedimentary rocks (Tvs) include tuffaceous shales and sandstones, rhyclitic and dacitic tuff, and flows. The tuffs commonly are partly or entirely welded, and the pores of the flow rocks are filled with calcite or zeolite so that porosity and permeability are low. Well yields of 10 to 100 gpm are usual; yields of more than 100 gpm are uncommon.

The pre-Tertiary rocks (pT) include intrusive igneous rocks such as diorite, granodiorite, and metamorphosed sedimentary and volcanic rocks such as arkose, graywacke, mafic flows, and schist. No well data are available, but similar rocks in other areas yield small to very small quantities of water. They crop out over only a small area in mountainous terrain and are unimportant as aquifers.

The aquifer unit map does not give a complete picture of the geographic distribution of aquifer units. At many places a few feet to a few hundred feet of alluvial deposits (QTal) overlie sedimentary strata (Ts), which, in turn, overlie volcanic rocks (Tb). All three of these may be aquifers at a particular place. Where information is available, this relation has been shown on the map as: QTal/Ts/Tb, or QTv/Tb. However, at many places data are not available to permit showing the sequence of aquifer units. Some inferences can be made, however. For example, it is very probable that where the alluvial deposits (QTal) are entirely surrounded by volcanic rocks (Tb), which are older than QTal, they would be encountered beneath the alluvium.

The general availability of ground water and the depth to the water table are shown on a map, figure 895. For maximum utility, that map and the aquifer unit map should be used together. The descriptions of the aquifer units, their general hydrologic characteristics, and the general quality of the water yielded by them are given in table 494.

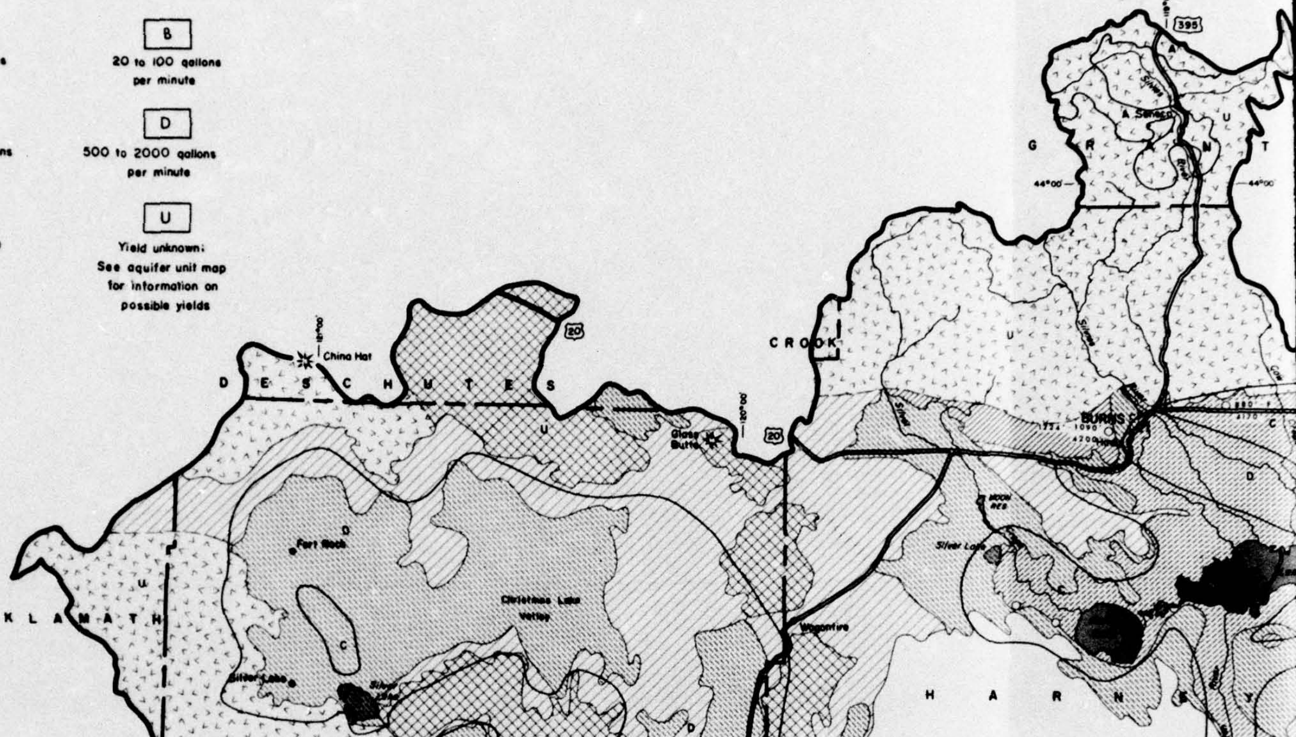
Table 494 - Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 12

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
QTal: Valley and basin fill deposits, chiefly alluvial and lacustrine but some eolian. Pliocene, Pleistocene, and Holocene in age.	Unconsolidated, fluviatile gravel, sand, and silt. Lacustrine gravel, silt, sand, clay, tuff, and diatomite. Includes some hot spring deposits, eolian sand, talus, and landslide deposits.	Clean, coarse-grained strata store and yield moderate to large supplies of water where they are below the water table. Yields are roughly proportional to thickness of strata below water table and commonly range from a few hundred to 1,000 gpm.	Dissolved solids less than 500 mg/l in much of area, but may exceed 1,000 mg/l at some places. Sodium commonly exceeds 50 percent.
QTv: Lava flows, forming cones and domes, and minor interbeds of tuffaceous sedimentary and pyroclastic rocks. Chiefly Pleistocene, some late Pliocene and Holocene in age.	Flows are chiefly basalt, basaltic andesite; commonly vesicular or scoriaceous; locally dense or platy. Pyroclastics include agglomerates, breccia, scoria, cinders, and ash flows.	Where 50 feet or a greater thickness lies below the water table, aquifer yields moderate to large quantities of water to wells. Some wells yield more than 2,500 gpm. In much of the area, unit is mostly or entirely above the water table.	Dissolved solids generally less than 500 mg/l. Water soft to moderately hard, may be high in sodium, and has excessive boron.
Ts: Chiefly tuffaceous sedimentary strata with some interbedded basalt flows and pyroclastic rocks. Includes Harney, Danforth, and Fort Rock Formations and similar strata. Chiefly of Pliocene age.	Massive tuff, tuffaceous siltstone and sandstone, ash, ashy diatomite, pumice, and scoria; sandstone, and conglomerate. Locally includes lightly cemented sand and gravel. Also contains some thin interflows of basaltic and rhyolitic lavas.	Wells in fine-grained strata yield only small quantities of water. Wells in flows, breccia, scoria, coarse sandstone may yield moderate to moderately large quantities. Specific capacities of poorer wells may be less than 1 gpm; better wells 5 to 50 gpm per foot of drawdown.	Dissolved solids generally less than 1,000 mg/l. Water generally moderately hard to hard. Percent sodium more than 50; boron may be excessive in some wells.
Tb: Basalt and andesite flows and flow breccia. Includes Steens Basalt, Picture Rock Basalt, Columbia River Group and minor interbeds of sedimentary rock. Chiefly Miocene, early Pliocene in age.	Basalt flows vesicular at places and, locally, porphyritic; platy andesite, basaltic andesite and dacite or rhyodacite flows; includes flow breccia, tuffaceous sedimentary rocks and tuffs. Younger flows generally open textured; pores in older flows partly or entirely filled.	Porosity and permeability moderately low, but where a few hundred feet or more thick will yield moderate to large supplies to wells. Such wells commonly yield a few hundred to 1,000 gpm; have specific capacities of 10 to 50 gpm per ft. Water table several hundred feet below surface in much of area.	Dissolved solids range from 100 to 1,000 mg/l. Sodium adsorption ratio, boron may be high in higher range of dissolved solids.
Tvs: Volcanic and sedimentary rocks, chiefly siliceous in composition. Includes John Day and Clarno Fms.	Rhyolitic and dacitic tuff, tuffaceous shale and sandstone; some tuffs are partly or entirely welded. Rhyodacitic and andesitic flows locally. Flows more abundant in lower part of unit. Pores of flow rocks commonly filled with calcite or zeolite.	Generally not a very productive unit; well yields 10 to 100 gpm. At some places coarser, less cemented or compacted units (sandstone, flows, flow breccia, pyroclastic rocks) may yield 100 to several hundred gallons per minute. Specific capacities of better wells on the order of 10 to 20 gpm per foot of drawdown.	Few data available. Dissolved solids probably generally less than 1,000 mg/l but in some areas may be much higher. Sodium and boron may be excessive.
pT: Intrusive and metamorphosed sedimentary rocks of pre-Tertiary age.	Gneissic granodiorite, quartz diorite, metamorphosed arkose, graywacke, porphyritic mafic flows, and schist. Exposed only on east flank of Pueblo Mountains and Seneca area.	No well data but unit probably has low porosity and permeability and would generally yield small quantities of water, perhaps only a few gallons per minute.	No data available. Quality probably ranges widely.

EXPLANATION

Quantity generally available per well

A — 1 to 20 gallons per minute	B — 20 to 100 gallons per minute
C — 100 to 500 gallons per minute	D — 500 to 2000 gallons per minute
E — More than 2000 gallons per minute	U — Yield unknown; See aquifer unit map for information on possible yields



LIMITS OF YIELD

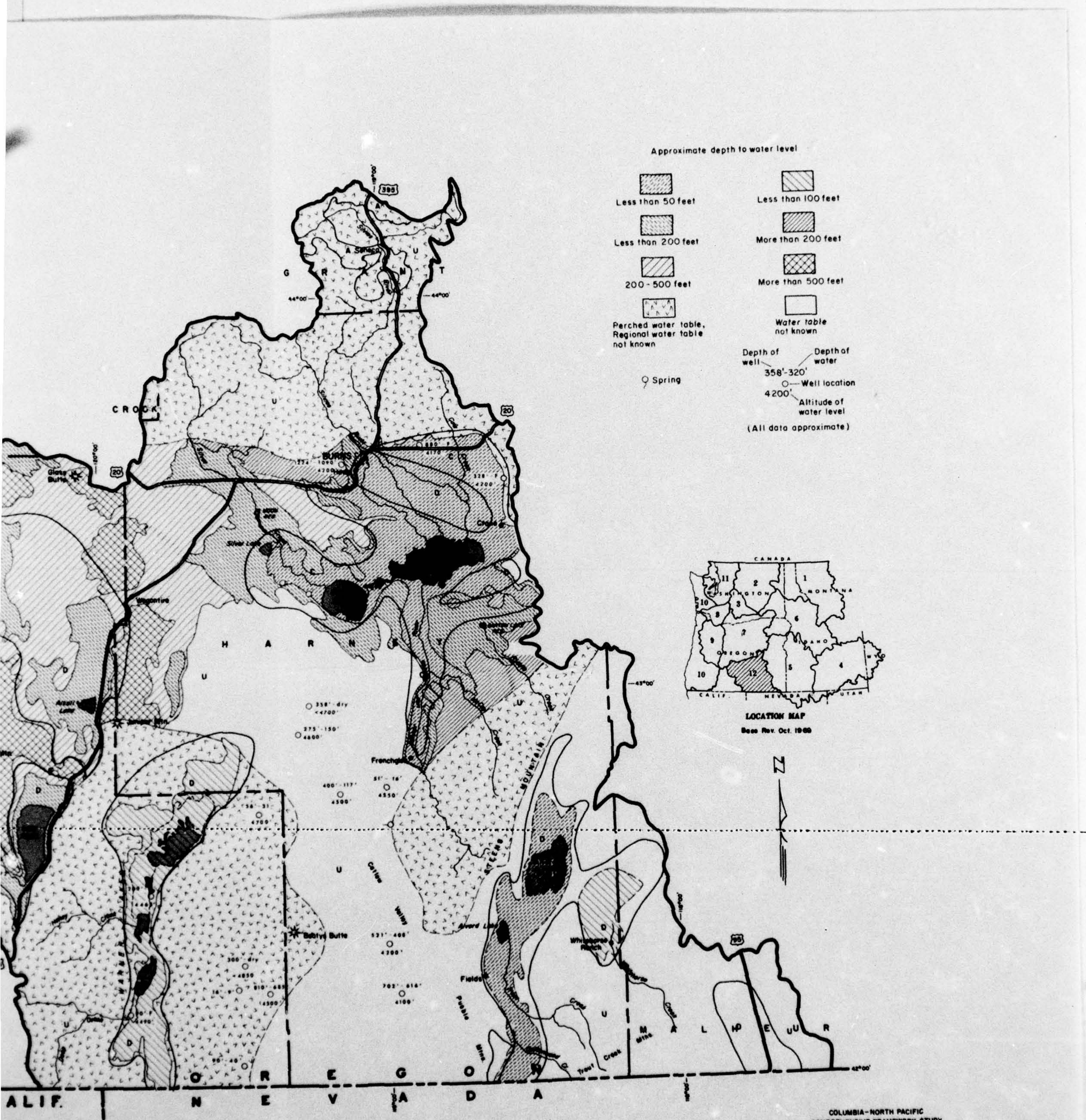
The map shows areas where properly located and properly constructed wells generally are capable of yielding amounts of water within the limits specified in the legend above.

The map does not indicate the total quantity of water that may be safely developed in any given area or aquifer; these determinations generally can be made only on the basis of special investigations.

Depth to water not indicated in areas where water levels are highly variable, differ significantly with depth, or change greatly in short lateral distances.

10 0 10 20

SCALE IN MILES



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER AND DEPTH TO WATER LEVEL

OREGON CLOSED BASIN
SUBREGION 12

FIGURE 895

2

Table 495 - Storage, Recharge, and Discharge of Ground Water in Aquifer Units, Subregion 12

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge		
						Inches Over Area		Net
	Sq. Mi.	Acres (1000's)	Specific Yield (percent)	Depth Used (ft)	Water (1000's ac-ft)	Gross	Net	(1000's ac-ft)
QTal	3,570	2,350	20	100	35,000 1/	2.0	2.0	400
QTv	2,790	1,770	5	100	4,400 1/	2	1	150
Ts	3,830	2,450	5	100	12,200	.5	.25	50
Tb	5,680	3,640	1	100	3,640	1	.5	150
Tvs	1,640	1,050	2	50	1,000	.5	.25	20
pT	200	128	1	50	60	.5	.25	2
TOTAL (rounded)	17,700	11,388			56,000			800

1/ In places, the younger volcanic rocks (QTv) and alluvial deposits (QTal) are entirely above the water table or have only a few feet of saturation. It is assumed that the volume of water in storage to the base of the aquifer or to a maximum of 100 feet below the water table is equivalent to the water stored to an average saturated thickness of 50 feet in the QTv, and 75 feet in the QTal, multiplied by the entire area of outcrop.

Water in Storage

The amount of water stored in a specified depth interval below the water table in each aquifer unit is given in table 495. That table also gives the outcrop area of the aquifer unit, the estimated specific yield for the depth interval used, and the depth interval.

Subregion 12 is generally a water-short area, and there appears to be a greater possibility for substantial lowering of the water table in this subregion than in any other. Therefore, the water in storage was calculated for a saturated depth of 100 feet for all aquifer units except the volcanic and sedimentary rocks (Tvs) and the pre-Tertiary rocks (pT). However, an adjustment was required for the alluvial deposits and the younger volcanic rocks because at places they are entirely above the water table or have only a few feet of saturation. About 56 million acre-feet of water is stored in the aquifers in Subregion 12--more than 60 percent in the alluvial deposits.

Natural Recharge and Discharge

Because Subregion 12 consists of a number of closed basins, there is no surface outflow from the subregion except for a few

intermittent streams that discharge into closed basins in Nevada. The geologic and hydrologic data indicate that subsurface outflow probably is an insignificant factor in the water budget; thus, practically all the water that leaves the basin does so by evapotranspiration. The water-level records available, figure 896, indicate that, although there have been some cyclic changes in water levels in specific observation wells, there has been no appreciable general change in the water table or in pressure levels in confined aquifers since observations began. Ground-water storage changes moderately from season to season and slightly from year to year; gains and losses approximately balance over a period of several years; and precipitation and evapotranspiration are about equal.

Precipitation ranges from more than 30 inches on the higher peaks along the southwestern margin and the northern end of the basin to less than 10 inches in the basins occupied by Silver, Summer, Malheur, Harney, and Alvord Lakes and in Catlow Valley. Recharge to and discharge from aquifers reflect the combination of distribution of precipitation and the physiography of the subregion. In general, the higher areas receiving heavier precipitation contribute both surface and ground water to the basin areas which collect not only all the water received by them as precipitation but also all water received by lateral inflow.

In the highland areas, bodies of perched ground water are common, and the perched water tables may be only a few feet below the surface. Generally, the perching layers are slightly permeable and are lenticular so that only part of the perched ground water is discharged into streams in the mountains. Another part leaks downward to the regional water table, which may be more than 1,000 feet below the land surface. Generally, there are a number of perched ground-water zones between the land surface and the water table. Some water discharges from each of these perched zones to enter the streams. When the streams reach the margins of the basins, part of their discharge becomes recharge to aquifers in the basins. Ground water reaching the regional water table in the upland areas moves laterally to the basins, where it is discharged by evapotranspiration through springs or by pumping. Some water enters confined aquifers before moving laterally into the basins and discharges through flowing wells or upward leakage through imperfectly confining beds to reach the water table.

The general circulation of ground water described above--downward and basinward in the mountainous recharge areas and upward in the discharge areas--prevails throughout Subregion 12. The mountains along the southwest flank of the subregion, the Blue Mountains north of Burns, Steens, Hart, and Warner Mountains, and the south end of Abert Rim--all are recharge areas. Silver, Summer, Abert, Warner, Harney, Malheur, and Alvord Lakes Basins are primarily discharge areas. In the discharge areas, recharge from local

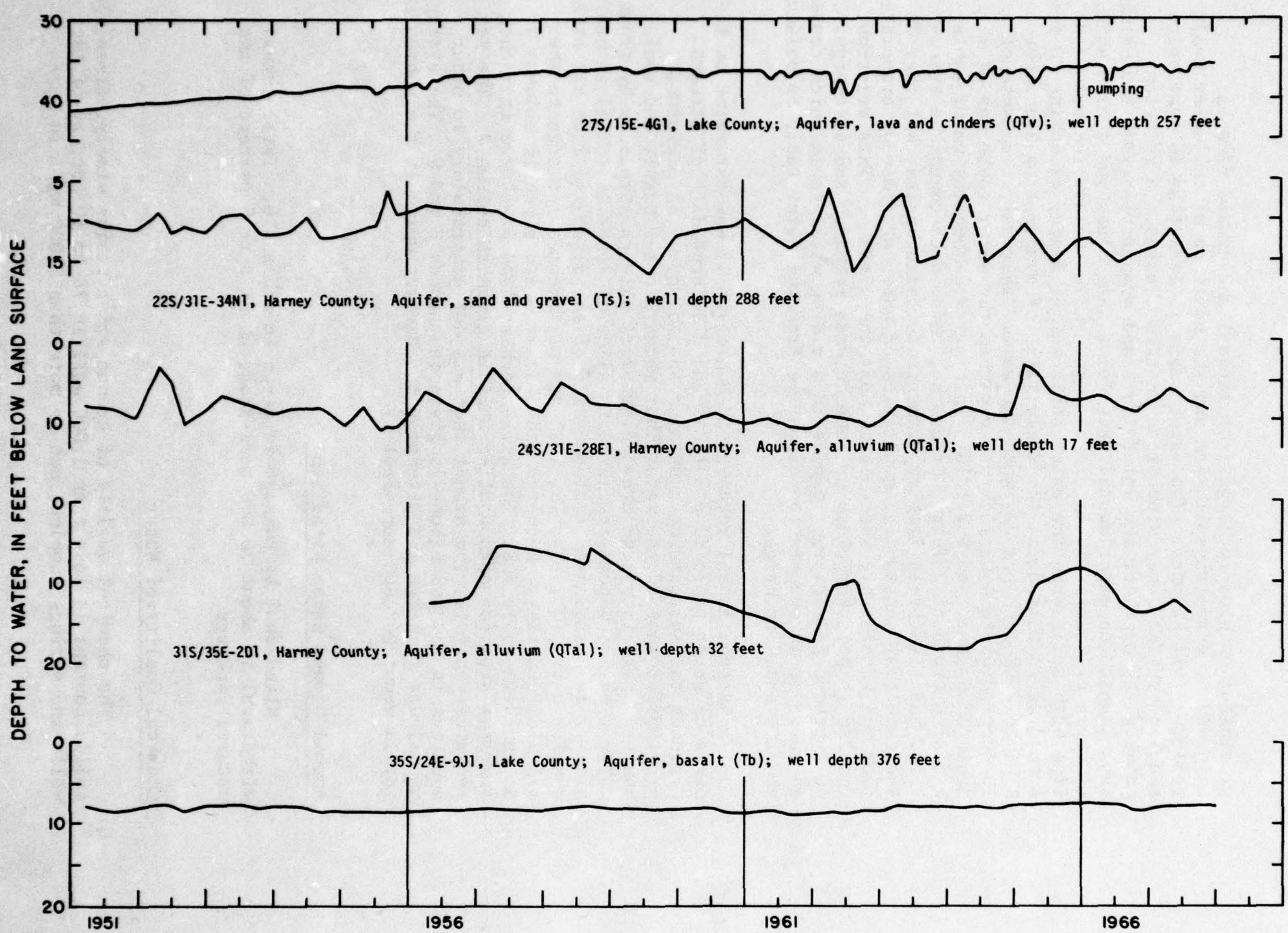


Figure 896 Hydrographs of selected wells in subregion 12

precipitation plus recharge from lateral and upward flow is balanced by evapotranspiration and the position of the water table reflects this balance. The water table is less than 10 feet below the land surface over wide areas in these basins. A relation between the depth of the water table and evaporation from the water table, based on experimental data for a sandy loam and a clay soil, is given by Bower. (5, figure 1) Measurable evaporation occurred from both soils when the water table was at depths exceeding 10 feet. According to this data, the daily rates of evaporation are about 0.01 to 0.02 inch per day when the water table was at a depth of 10 feet, 0.05 to 0.08 inch per day when the water table was at a depth of 5 feet, and 0.2 to 0.5 inch per day when the water table was at a depth of 2 feet. Of course, these data cannot be translated quantitatively from experiments to large basins, but they do indicate that substantial quantities of water are lost by evaporation from the water table where it is near the surface. This relation results in a rather close balance between recharge and discharge. An increase in recharge results in a rising water table which causes an increase in evaporation discharge from the water table to balance the increased recharge.

Average annual recharge in Subregion 12 was estimated on the basis of water table fluctuations and discharge data of streams draining the surrounding mountains and uplands. As explained previously, some of the water that recharges the basalt and sedimentary rocks in upland areas discharges through stream or by groundwater flow and becomes recharge to alluvial deposits (QTal) in basin areas. It was assumed that one-half of the discharge from all other aquifer units (QTv, Ts, Tb, Tvs, and pT) becomes recharge to the alluvial deposits. Recharge and discharge are given in columns 7, 8, and 9 in table 495. The gross recharge and discharge in inches over the area for each aquifer unit is given in column 7. The net recharge--that is, the amount that was not contributory to other aquifers in the subregion--is given in columns 8 and 9. The average annual net recharge and discharge for aquifer units in the subregion totals about 800,000 acre-feet.

Annual Ground-Water Withdrawal

Withdrawal by pumpage is given in table 496. Total annual withdrawal is about 70,000 acre-feet, about 8 or 9 percent of the natural recharge.

Chemical Quality of Water

The chemical quality of ground water varies widely; dissolved-solids content is less than 1,000 mg/l in 75 to 80 percent of the wells and springs sampled, but is more than 5,000 mg/l in some

AD-A036 573 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

UNCLASSIFIED NL

6 OF 6
AD
A036573

END
DATE
FILMED
3-77

samples. Percent sodium exceeded 50 in more than half of the samples and was more than 90 in some samples. Boron is excessive at many places. Water temperatures generally range from 48° to 55°F., but some wells and springs yield warm to hot water.

Present Use and Future Availability

Present use of ground water is based on data for 1965 to 1967 projected to the base period of 1970. Projection of municipal, domestic, and industrial use is based on estimated population growth. Irrigation use was on the basis of past rates of increase, modified for special situations. Ground-water withdrawal and the amount used consumptively are given in table 496. Because some of the return flow may be into streams, net ground-water withdrawal may exceed consumptive use. Generally, however, in most areas where significant amounts of ground water are withdrawn, a large part of the water not used consumptively returns to the ground. Present ground-water withdrawal is estimated to be about 70,000 acre-feet, and consumptive use about 30,000 acre-feet annually. Net withdrawal is slightly more than consumptive use, but probably does not exceed 40,000 acre-feet, about 5 percent of the net natural annual discharge from the aquifers in the area. Furthermore, in comparison with the volume of water in storage in the upper 100 feet of saturation, the present use is insignificant.

Large areas underlain by aquifer units known to be productive at other places in the subregion are unexplored. The general availability of ground water is indicated in figure 895, which delineates areas in which wells within specified ranges in yield can generally be obtained. It should not be inferred that all wells in the area will have yields within the specified range; however, most of them probably will. It should be noted that the areas delineated are rather closely related to depth-to-water zones. This suggests that adjacent areas may also be underlain by permeable aquifers; but, because of the greater depth to water, the water yielding ability has never been proven by production wells.

Figure 895 also shows a few wells and depths to the water table in areas where data were too sparse for delineating depth ranges. A few of the larger springs also are shown.

Some of the deterrents to development result from the high altitude, the short growing season, and the considerable depth to water in much of the area shown in figure 895. Some water samples had excessive dissolved solids, sodium, or boron; and these waters are not entirely suitable for irrigation.

Table 496 - Estimated Ground-Water Withdrawal and Consumptive Use
Subregion 12, 1970

	Ac-ft per year; all quantities in thousands
Irrigation	
Acres irrigated	18
Withdrawal	60
Consumptive use	30
Industrial 1/	
Withdrawal	6
Consumptive use 2/	.3
Public Supplies	
Persons served	6
Withdrawal	2.5
Consumptive use 3/	.5
Rural-Domestic	
Persons served	4
Withdrawal 4/	.45
Consumptive use 5/	.22
Stock	
Withdrawal and consumptive use 6/	.12
TOTAL WITHDRAWAL (rounded)	70
TOTAL CONSUMPTIVE USE (rounded)	30

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

Artificial Recharge

There is no known artificial recharge of aquifers in Subregion 12 at the present time. However, the late Tertiary and Quaternary volcanics (QTv) and Tertiary basalt (Tb) are partly or entirely above the water table over extensive areas and are suitable for artificial recharge. Storage space is available for many millions of acre-feet of water.

Water Rights

Subregion 12 consists essentially of the Malheur and Summer Lake Basins (Oregon Water Resources Board Basins 12 and 13, minus Goose Lake Basin, plus a small part of Basin 11). Primary water rights for 231 wells are on file with the State Engineer's Office as of March 1967. Prime rights allow withdrawal of 99,407 acre-feet a year, of which 85,768 acre-feet is for irrigation of 28,589 acres. The maximum rate of withdrawal is 322 cfs (144,000 gpm) during the irrigation season. Data on supplemental water rights are not available. Ground-water rights are summarized by major-use category in table 497.

Table 497 - Summary of Ground-Water Rights, Subregion 12, 1967

Basin No.	Basin Name	Number of Wells	Domestic (ac-ft)	Municipal (ac-ft)	Industrial (ac-ft)	Irrigation (acres)	Irrigation (ac-ft)	Other (ac-ft)	Total (ac-ft)
11	Owyhee1/	3	0	0	319	528	1,584	0	1,903
12	Malheur Lake	127	128	2,737	9,615	16,339	49,018	0	61,498
13	Goose and Summer Lakes2/	101	23	0	187	11,722	35,166	630	36,006
TOTAL		231	151	2,737	10,121	28,589	85,768	630	99,407

1/ That portion of Owyhee Basin within the subregion.
2/ Minus the Goose Lake Basin.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

Subregion 12 is fringed by a number of fairly high mountains that receive 20 to 30 inches of rainfall annually. In some of these high areas, ground water is effluent to the streams throughout the year. Generally, the streams become influent to the ground water immediately upon reaching the margin of the basin or lowland and gradually diminish in discharge. In wet seasons and in wet cycles, some of the streams maintain a flow to the central part of the basin where they discharge into temporary or permanent lakes. During dry seasons, because of stream channel losses, evapotranspiration, and diversions for irrigation, they may not even reach the margin of the lowland. The ground-water contribution to two streams in the subregion is illustrated by the hydrographs shown on figure 897. The probable ground-water component of each of these streams usually ranges between 30 and 100 cfs.

Some streams are almost entirely supported by discharge of springs, as Ana River near Summer Lake and Bridge Creek near Frenchglen.

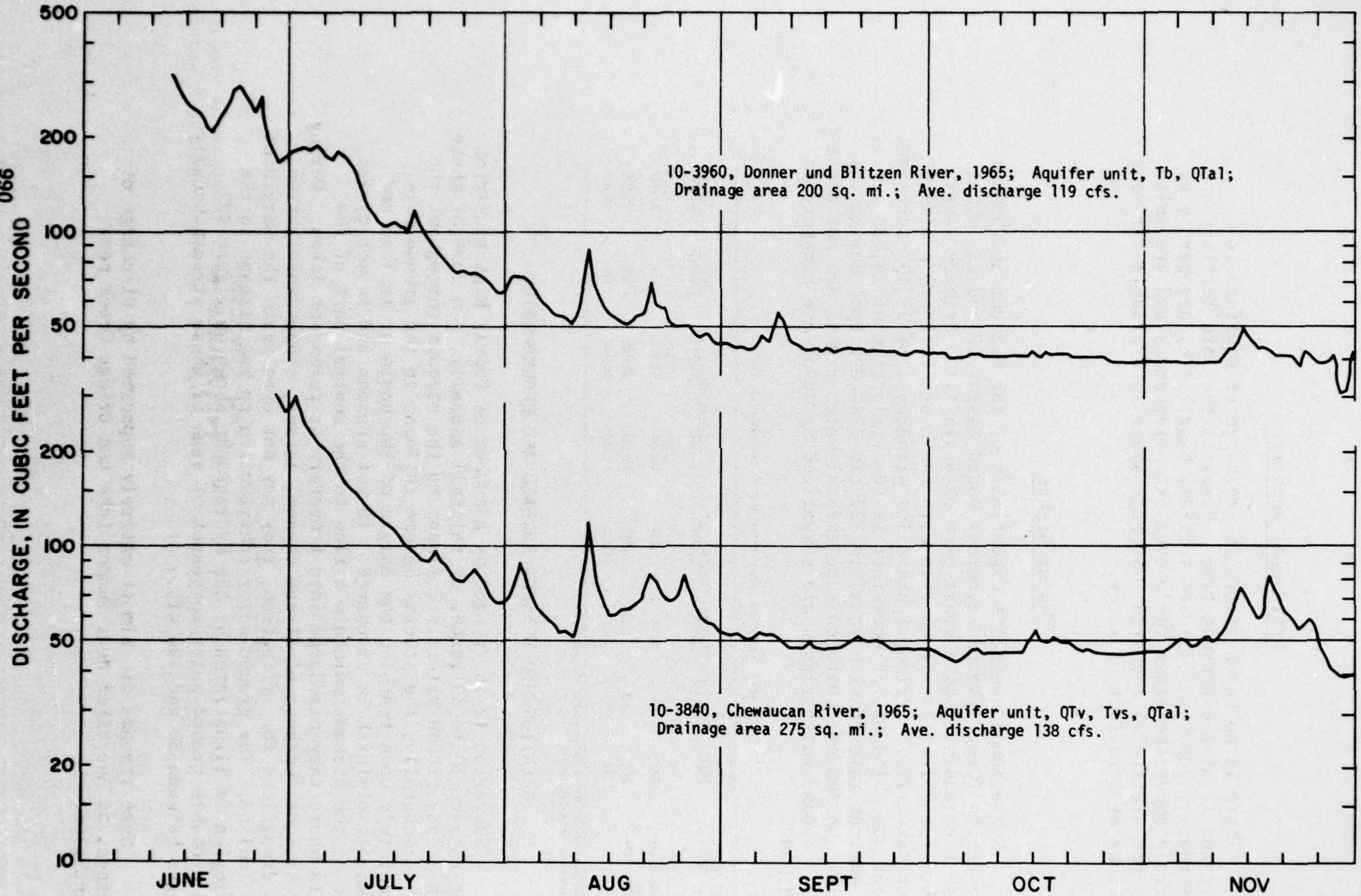


Figure 897 Hydrographs showing low-flow characteristics of selected streams

BIBLIOGRAPHY

1. Anderson, K. E., Geology and Ground-Water Resources of the Rathdrum Prairie Project and Contiguous Area, Idaho-Washington, U.S.D.I. Bureau of Reclamation unpublished report, 1951.

2. Beard, L. R., Statistical Methods in Hydrology, U. S. Army, Corps of Engineers, 1962.

3. Beattie, Byron, Harvesting the National Forest Water Crop, U.S.D.A., Forest Service, Paper Presented at the 36th Annual Convention of the National Reclamation Association, Honolulu, Hawaii, 1967.

4. Bodhaine, G. L., and others, The Role of Water in Shaping the Economy of the Pacific Northwest, Pacific Northwest Economic Base Study for Power Markets, vol. II, pt. 10, U.S.D.I. Bonneville Power Administration, 1965.

5. Bower, C. A., Salinity Control in Irrigation Agriculture, Salinity Laboratory, Agr. Research Service, U.S.D.A. (Presented at seminar on water logging and salinity problems, Nov. 1964, Lahore, West Pakistan.)

6. Brietkrietz, Alex, Basic Water Data Report No. 1, Missoula Valley, Montana, Montana Bureau of Mines and Geology Bulletin 37, 1964.

7. Brown, C. E., and Thayer, T. P., Geologic Map of the Canyon City Quadrangle, Northeastern Oregon, U.S.D.I. Geological Survey Misc. Geol. Inv. Map I-447, 1966.

8. Brown, S. G., Occurrence of Ground Water near Ana Springs, Lake County, Oregon, U.S.D.I. Geological Survey Open-File Report, 1957.

9. Brown, S. G., Problems of Utilizing Ground Water in the West-Side Business District of Portland, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1619-0, 1963.

10. Brown, S. G., and Newcomb, R. C., Ground-Water Resources of Cow Valley, Malheur County, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1619-M, 1962.

11. Brown, S. G., and Newcomb, R. C., Ground-Water Resources of the Coastal Sand-Dune Area North of Coos Bay, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1619-D, 1963.

12. Burnham, W. L., and others, Ground Water Conditions in Idaho, Idaho Department of Reclamation, Water Information Bulletin 1, 1966.

13. California Water Pollution Control Board, Water Quality Criteria, Publication 3-A, 1963.

14. Calkins, F. C., Geology and Water Resources of a Portion of East-Central Washington, U.S.D.I. Geological Survey Water-Supply Paper 118, 1905.

15. Carr, J. K., Alternate Plan for Mountain Home Project, Idaho. Memorandum Report on an Alternate Plan, Mountain Home Irrigation Project, Idaho, Committee on Interior and Insular Affairs, Print No. 4, 83d Congress 1st Session 1953.

16. Columbia Basin Inter-Agency Committee, Streamflow Depletion, Columbia River Basin, Water Management Subcommittee, CBIAC, Portland, Oregon, 1957.

17. Columbia Basin Inter-Agency Committee, Inventory of Published and Unpublished Sediment-Load Data in the Pacific Northwest, 1961, Water Supply and Water Pollution Control Subcommittee, CBIAC, Portland, Oregon, 1962.

18. Columbia Basin Inter-Agency Committee, Bibliography of Published Climatological Data, Columbia Basin States, Meteorology Subcommittee, CBIAC, Portland, Oregon, 1965.

19. Columbia Basin Inter-Agency Committee, River Mile Indexes, Columbia River Basin, Hydrology Subcommittee, CBIAC, Portland, Oregon, 1963-1968.

20. Corcoran, R. E., and others, Geology of the Mitchell Butte Quadrangle, Oregon, Oregon Department of Geology and Mineral Industries Geol. Map Series GMS-2, 1962.

21. Crosthwaite, E. G., Ground-Water Possibilities South of the Snake River Between Twin Falls and Pocatello, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1460-C, p. 99-145, 1957.

22. Crosthwaite, E. G., Ground-Water Reconnaissance in Round Valley, Custer County, Idaho, U.S.D.I. Geological Survey Open-File Report, 1962.

23. Crosthwaite, E. G., Ground-Water Reconnaissance of the Sailor Creek Area, Owyhee, Elmore, and Twin Falls Counties, Idaho, U.S.D.I. Geological Survey Open-File Report, 1963.

24. Crosthwaite, E. G., and George, R. S., Reconnaissance of the Water Resources of the Upper Lemhi Valley, Lemhi County, Idaho, U.S.D.I. Geological Survey Open-File Report, 1965.

25. Crosthwaite, E. G., Mundorff, M. J., and Walker, E. H., Ground-Water Aspects of the Lower Henrys Fork Region, Idaho, U.S.D.I. Geological Survey Open-File Report, 1967.

26. Crosthwaite, E. G., and Scott, R. C., Ground Water in the North Side Pumping Division, Minidoka Project, Minidoka County, Idaho, U.S.D.I. Geological Survey Circular 371, 1956.

27. Eakin, T. E., Ground-Water Resources of the Waterville Area, Douglas County, Washington, U.S.D.I. Geological Survey Open-File Report, 1946.

28. Eakin, T. E., Ground-Water Appraisal of Independence Valley, Western Elko County, Nevada, Nevada Department of Conservation and Natural Resources, Ground-Water Reconnaissance Series Report No. 8, 1962.

29. Fader, S. W., Water Levels in Wells and Lakes in Rathdrum Prairie and Contiguous Areas, Bonner and Kootenai Counties, Northern Idaho, U.S.D.I. Geological Survey Open-File Report, 1951.

30. Flaxman, E. M., and High, R. D., Sedimentation in Drainage Basins of the Pacific Coast States, U.S.D.A. 1955.

31. Fowler, K. H., Preliminary Report on Ground Water in the Salmon Falls Area, Twin Falls County, Idaho, U.S.D.I. Geological Survey Circular 436, 1960.

32. Foxworthy, B. L., Geology and Ground-Water Resources of the Ahtanum Valley, Yakima County, Washington, U.S.D.I. Geological Survey Water-Supply Paper 1598, 1962.

33. Foxworthy, B. L., and Bryant, C. T., Artificial Recharge Through a Well Tapping Basalt Aquifer at The Dalles, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1594-E, 1967.

34. Foxworthy, B. L. and Washburn, R. L., Reconnaissance Investigation of Ground Water in the Wellpinit Area, Stevens County, Washington, U.S.D.I. Geological Survey Open-File Report, 1957.

35. Foxworthy, B. L., and Washburn, R. L., Ground Water in the Pullman Area, Whitman County, Washington, U.S.D.I. Geological Survey Water-Supply Paper 1655, 1963.

36. Garling, M. E., Molenaar, Dee, and others, Water Resources and Geology of the Kitsap Peninsula and Certain Adjacent Islands, Washington Division of Water Resources Water Supply Bulletin No. 18, 1965.

36A. Frank, F. J., Ground Water in the Clatsop County Sand Dunes, U.S.D.I. Geological Survey Open-File Report, April 1968.

37. Gilluly, James, Geology and Mineral Resources of the Baker Quadrangle, Oregon, U.S.D.I. Geological Survey Bulletin 879, 1937.

38. Goldblatt, E. L., Van Denburgh, A. S., and Marsland, R. A., The Unusual and Widespread Occurrence of Arsenic in Well Waters of Lane County, Oregon, Lane County Department of Health, 1963.

39. Griffin, W. C., Sceva, J. E. Swenson, H. A., and Mondorff, M. J., Water Resources of the Tacoma Area, Washington, U.S.D.I. Geological Survey Water-Supply Paper 1499-B, 1962.

40. Griffin, W. C., Watkins, F. A., Jr., and Swenson, H. A., Water Resources of the Portland, Oregon and Vancouver, Washington Area, U.S.D.I. Geological Survey Circular 372, 1956.

41. Hadley, R. F., Hydrology of Stock-Water Development in Southeastern Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1475-P, p. 563-599, 1963.

42. Hampton, E.R. Ground Water in the Coastal Dune Area Near Florence, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1539-K, 1963.

43. Hampton, E. R., Records of Wells, Water Levels, and Chemical Quality of Ground Water in the Molalla-Salem Slope Area, Northern Willamette Valley, Oregon, Oregon Ground-Water Report No. 2, 1963.

44. Hampton, E. R., Geologic Factors that Control the Occurrence and Availability of Ground Water in the Fort Rock Basin, Lake County, Oregon, U.S.D.I. Geological Survey Professional Paper 383-B, 1964.

45. Hampton, E. R., Evaluation of Potential Sources of Water in Crater Lake National Park, Oregon, U.S.D.I. Geological Survey Open-File Report, 1967.

46. Hampton, E. R., and Brown, S. G., Geology and Ground-Water Resources of the Upper Grande Ronde River Basin, Union County, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1597, 1964.

47. Hart, D. H., Tests of Artesian Wells in the Cold Creek Area, Washington, U.S.D.I. Geological Survey Open-File Report, 1958.

48. Hart, D. H., and Newcomb, R. C., Geology and Ground Water of the Tualatin Valley, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1697, 1965.

49. Haushild, W. L., and others, Radionuclide Transport of the Columbia River, Pasco to Vancouver, Washington Reach, U.S.D.I. Geological Survey Open File Report, p. 16-42, 1966.

50. Highsmith, R. M., Jr., and Leverenz, J. M., Atlas of the Pacific Northwest Resources and Development, Oregon State University Press (Corvallis), 1962.

51. Hodge, E. T., Geology of North Central Oregon, Oregon University Studies in Geology No. 3, 1942, Eugene, Oregon.

52. Hogenson, G. M., Geology and Ground Water of the Umatilla River Basin, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1620, 1964.

53. Hogenson, G. M., and Foxworthy, B. L., Ground Water in the East Portland Area, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1793, 1965.

54. Huntting, M.T., and others, Geologic Map of Washington, Washington Division of Mines and Geology, 1961.

55. Iorns, W. V., Hembree, C. H., and Oakland, G. L., Hydrologic Techniques and Criteria Used in Appraising Surface-Water Resources in Water Resources of the Upper Colorado River Basin, U.S.D.I., Geological Survey Professional Paper 441, p. 41-63, 1965.

56. Johnson, A. I., Specific Yield-Compilation of Specific Yields for Various Materials, U.S.D.I. Geological Survey Water-Supply Paper 1662-0, 1967.

57. Kilburn, Chabot, Ground Water for Irrigation in the Upper Part of the Teton Valley, Teton Counties, Idaho and Wyoming, U.S.D.I. Geological Survey Water-Supply Paper 1789, 1964.

58. Kinnison, H. B., and Sceva, J. E., Effects of Hydraulic and Geologic Factors on Streamflow of the Yakima River Basin, U.S.D.I. Geological Survey Water-Supply Paper 1595, 1963.

59. Kirkham, V. R. D., Ground Water for Municipal Supply at Saint Maries, Idaho, Idaho Bureau of Mines and Geology Pamphlet 17, 1926.

60. Kirkham, V. R. D., Ground Water for Municipal Supply at Potlatch, Idaho, Idaho Bureau of Mines and Geology Pamphlet 23, 1927.

61. Kirkham, V. R. D., Underground Water Resources in the Vicinity of Orofino and Lapwai, Idaho, Idaho Bureau of Mines and Geology Pamphlet 24, 1927.

62. Konizeski, R. L., McMurtrey, R. G., and Brietkrietz, Alex, Preliminary Report on the Geology and Ground-Water Resources of the Northern Part of the Deer Lodge Valley, Montana, Montana Bureau of Mines and Geology Bulletin 21, 1961.

63. Konizeski, R. L., McMurtrey, R. G., and Brietkrietz, Alex, Preliminary Report on the Geology and Ground-Water Resources of the Southern Part of the Deer Lodge Valley, Montana, Montana Bureau of Mines and Geology Bulletin 31, 1962.

64. Laird, L. B., Chemical Quality of the Surface Waters of the Snake River Basin, U.S.D.I. Geological Survey Professional Paper 417-D, 1964.

65. Laird, L. B., Eastern Washington Floods of December 21-31, 1964 and January 27-February 1, 1965, Report of Meeting on Erosion and Sedimentation, 1964-65 Flood Season, Columbia Basin Interagency Committee, p. 19-22, 1965.

66. Laird, L. B., and Walters, K. L., Municipal, Industrial, and Irrigation Water Use in Washington, 1965, U.S.D.I. Geological Survey Open-File Report, 1967.

67. Liesch, B. A., Price, C. E., and Walters, K. L., Geology and Ground-Water Resources of Northwestern King County, Washington, Washington Division of Water Resources Water Supply Bulletin 20, 1963.

68. Littleton, R. T., and Crosthwaite, E. G., Ground-Water Geology of the Bruneau-Grand View Area, Owyhee County, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1460-D, p. 147-198, 1957.

69. Love, J. D., Weitz, J. L., and Hose, R. K., Geologic Map of Wyoming, U.S.D.I. Geological Survey, 1955

70. Lystrom, D. J., Nees, W. L., and Hampton, E. R., Ground Water of Baker Valley, Baker County, Oregon, U.S.D.I. Geological Survey Hydrologic Investigations Atlas HA-242, 1967.

71. MacKichan, K.A., and Kammerer, J.C., Estimated Use of Water in the United States, U.S.D.I. Geological Survey Circular 456, 1961.

72. Malde, H. E., Powers, H. A., and Marshall, C. H., Reconnaissance Geologic Map of West-Central Snake River Plain, Idaho, U.S.D.I. Geological Survey Miscellaneous Geologic Investigations, Map I-373, 1963.

73. McConnell, J. B., Chemical Quality Investigations of Surface Water in Idaho, 1965-66, U.S.D.I. Geological Survey Open-File Report, 1967.

74. McMurtrey, R. G., Konizeski, R. L., and Brietkrietz, Alex, Geology and Ground-Water Resources of the Missoula Basin, Montana, Montana Bureau of Mines and Geology Bulletin 47, 1965.

75. McMurtrey, R. G., Konizeski, R.L., and Stermitz, Frank, Preliminary Report on the Geology and Water Resources of the Bitterroot Valley, Montana, With a Section on Chemical Quality of Water by H. A. Swenson, Montana Bureau of Mines and Geology Bulletin 9, 1959.

76. Meier, M. F., Distribution and Variation of Glaciers in the United States Exclusive of Alaska, International Association of Science Hydrology Publication 54, 1963.

77. Meinzer, O. E., Artesian Water for Irrigation in Little Bitterroot Valley, Montana, U.S.D.I. Geological Survey Water-Supply Paper 400-B, p. 9-37, 1916.

78. Meinzer, O. E., Ground Water in the Pahsimeroi Valley, Idaho, Idaho Bureau of Mines and Geology Pamphlet 9, 1924.

79. Montgomery, K. M., Preliminary Geologic Map of Nevada, U.S.D.I. Geological Survey unpublished map, 1965.

80. Mundorff, M. J., Ground Water in Birch Creek Valley, Idaho, U.S.D.I. Geological Survey Open-File Report, 1962.

81. Mundorff, M. J., The Feasibility of Artificial Recharge in the Snake River Basin, Idaho, U.S.D.I. Geological Survey Open-File Report, 1962.

82. Mundorff, M. J., Geology and Ground-Water Conditions of Clark County, Washington, With a Description of a Major Alluvial Aquifer Along the Columbia River, U.S.D.I. Geological Survey Water-Supply Paper 1600, 1964.

83. Mundorff, M. J., Ground Water in the Vicinity of American Falls Reservoir, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1846, 1967.

84. Mundorff, M. J., and Bodhaine, G. L., Investigation of the Rise in the Level of Soap Lake at Soap Lake, Washington, U.S.D.I. Geological Survey Open-File Report, 1954.

85. Mundorff, M. J., Broom, H. C., and Kilburn, Chabot, Reconnaissance of the Hydrology of the Little Lost River Basin, U.S.D.I. Geological Survey Water-Supply Paper 1539-Q, 1963.

86. Mundorff, M. J., Crosthwaite, E. G., and Kilburn, Chabot, Ground Water for Irrigation in the Snake River Basin in Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1654, 1964.

87. Mundorff, M. J., Reis, D. J., and Strand, J. R., Progress Report on Ground Water in the Columbia Basin Project, Washington, U.S.D.I. Geological Survey Open-File Report, 1952.

88. Mundorff, M. J., and Sisco, H. G., Ground Water in the Raft River Basin, Idaho, with Special Reference to Irrigation Use, U.S.D.I. Geological Survey Water-Supply Paper 1619-CC, 1963.

89. Mundorff, M. J., and Travis, W. I., Water Supply for a Fish-Hatching Site, Clearwater Valley, Idaho, U.S.D.I. Geological Survey Open-File Report, 1962.

90. Mundorff, M. J., Weigle, J. M., and Holmberg, G. D., Ground Water in the Yelm Area, Thurston and Pierce Counties, Washington, U.S.D.I. Geological Survey Circular 356, 1955.

91. Murray, C. R., Estimated Use of Water in the United States, U.S.D.I. Geological Survey Circular 556, 1968.

92. Nace, R. L., and Fader, S. W., Records of Wells on Rathdrum Prairie, Bonner and Kootenai Counties, Northern Idaho, U.S.D.I. Geological Survey Open-File Report, 1951.

93. Nace, R. L., and others, Water Resources of the Raft River Basin, Idaho-Utah, U.S.D.I. Geological Survey Water-Supply Paper 1587, 1961.

94. Nace, R. L., West, S. W., and Mower, R. W., Feasibility of Ground-Water Features of the Alternate Plan for the Mountain Home Project, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1376, 1957.

95. Newcomb, R. C., Ground Water in the South Bay Area, Grays Harbor, Washington, U.S.D.I. Geological Survey Open-File Report, 1947.

96. Newcomb, R. C., Ground-Water Resources of Snohomish County, Washington, U.S.D.I. Geological Survey Water-Supply Paper 1135, 1952.

97. Newcomb, R. C., Ground-Water Available for Irrigation in the Fort Rock Basin, Northern Lake County, Oregon, U.S.D.I. Geological Survey Open-File Report, 1953.

98. Newcomb, R. C., Ground Water of the Columbia Basin, U.S.D.I. Geological Survey Open-File Report, 1959.

99. Newcomb, R. C., Ground Water in the Western Part of the Cow Creek and Soldier Creek Grazing Units, Malheur County, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1475-E p. 159-172, 1961.

100. Newcomb, R. C., Storage of Ground Water Behind Subsurface Dams in the Columbia River Basalt, Washington, Oregon, and Idaho, U.S.D.I. Geological Survey Professional Paper 383-A, 1961.

101. Newcomb, R. C., Geology and Ground-Water Resources of the Walla Walla River Basin, Washington-Oregon, Washington Division of Water Resources, Water Supply Bulletin 21, 1965.

102. Newcomb, R.C., Sceva, J.E., and Stromme, Olaf, Ground-Water Resources of Western Whatcom County, Washington, U.S.D.I. Geological Survey Open-File Report, 1949.

103. Newcomb, R. C., and Strand, J.R., Geology and Ground-Water Characteristics of the Hanford Reservation of the Atomic Energy Commission, Washington, U.S.D.I. Geological Survey. (In review.)

104. Noble, J.B., A Preliminary Report on the Geology and Ground-Water Resources of the Sequim-Dungeness Area, Clallam County, Washington, Washington División of Water Resources Water Supply Bulletin 11, 1960.

105. Noble, J. B., and Wallace, E. F., Geology and Ground-Water Resources of Thurston County, Washington, Washington Division of Water Resources Water Supply Bulletin 10, vol. 2, 1966.

106. Oregon Water Resources Board, Umpqua River Basin, State of Oregon Water Resources Board, 1958.

107. Oregon Water Resources Board, Rogue River Basin, State of Oregon Water Resources Board, 1959.

107A. Oregon Water Resources Board, Grande Ronde River Basin, State of Oregon Water Resources Board, 1960.

108. Oregon Water Resources Board, Deschutes River Basin, State of Oregon Water Resources Board, 1961.

109. Oregon Water Resources Board, North Coast Basin, State of Oregon Water Resources Board, 1961.

109A. Oregon Water Resources Board, Upper Willamette River Basin, State of Oregon Water Resources Board, 1961.

110. Oregon Water Resources Board, John Day Basin, State of Oregon Water Resources Board, 1962.

111. Oregon Water Resources Board, South Coast Basin, State of Oregon Water Resources Board, 1963.

112. Oregon Water Resources Board, Umatilla Basin, State of Oregon Water Resources Board, 1963.

112A. Oregon Water Resources Board, Middle Willamette River Basin, State of Oregon Water Resources Board, 1963.

113. Oregon Water Resources Board, Hood Basin, State of Oregon Water Resources Board, 1965.

114. Oregon Water Resources Board, Midcoast Basin, State of Oregon Water Resources Board, 1965.

114A. Oregon Water Resources Board, Lower Willamette River Basin, State of Oregon Water Resources Board, 1965.

114B. Oregon Water Resources Board, Malheur Lake Basin, State of Oregon Water Resources Board, 1967.

114C. Oregon Water Resources Board, Powder River Basin, State of Oregon Water Resources Board, 1967.

114D. Oregon Water Resources Board, Willamette River Basin, State of Oregon Water Resources Board, 1967.

115. Pacific Northwest River Basins Commission, 1967 National Assessment, Chapter 16, Columbia-North Pacific Region, Water Resources Council, 1968.

116. Peck, D.L., Griggs, A.B., Schlicker, H. G., Wells, F.G., and Dole, H.M., Geology of the Central and Northern Parts of the Western Cascade Range in Oregon, U.S.D.I. Geological Survey Professional Paper 449, 1964.

117. Piper, A.M., Geology and Ground-Water Resources of The Dalles Region, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 659-B, p. 107-189, 1932.

118. Piper, A.M., Ground-Water Resources of the Willamette Valley, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 890, 1942.

119. Piper, A.M., and Huff, L.C., Some Ground-Water Features of the Rathdrum Prairie-Spokane Valley Area, Idaho-Washington, with Respect to Seepage Loss from Pend Oreille Lake, U.S.D.I. Geological Survey Open-File Report, 1943.

120. Piper, A.M., and LaRocque, G.A., Jr., Water-Table Fluctuations in the Spokane Valley and Continguous Area, Washington-Idaho, U.S.D.I. Geological Survey Water-Supply Paper 889-B, p. 83-139, 1944.

121. Piper, A.M., Robinson, T.W., and Park, C.F., Jr., Geology and Ground-Water Resources of the Harney Basin, Oregon, with a Statement on Precipitation and Tree Growth by L. T. Jessup, U.S.D.I. Geological Survey Water-Supply Paper 841, 1939.

122. Price, C. E., Artificial Recharge Through a Well Tapping Basalt Aquifer, Walla Walla Area, Washington, U.S.D.I. Geological Survey Water-Supply Paper 1594-A, 1961.

123. Price, Don, Geology and Water Resources in the French Prairie Area, Northern Willamette Valley, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1833, 1967.

124. Price, Don, Ground-Water Reconnaissance in the Burnt River Valley Area, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1839-I, 1967.

125. Price, Don, Hart, D.H., and Foxworthy, B.L., Artificial Recharge in Oregon and Washington, 1962. U.S.D.I. Geological Survey Water-Supply Paper 1594-C, 1965.

125A. Price, Don, Ground Water in the Eola-Amity Hills Area, Northern Willamette Valley, Oregon, U.S.D.I. Geological Survey Water Supply Paper 1847, 1967.

126. Rainwater, F. H., Stream Composition of the Conterminous United States, U.S.D.I. Geological Survey Hydrologic Investigations Atlas, HA-61, 1962.

127. Rantz, S. E., and Moore, A.M., Floods of December 1964 in the Far Western States, U.S.D.I. Geological Survey Open-File Report, 1965.

128. Roberts, A.E., Geology and Coal Resources of the Toledo-Castle Rock District, Cowlitz and Lewis Counties, Washington, U.S.D.I. Geological Survey Bulletin 1062, 1958.

128A. Robinson, J.R., Estimated Existing & Potential Ground-Water Storage in Major Drainage Basins in Oregon, U.S.D.I. Geological Survey Open-File Report, April 1968.

129. Robinson, J. W., and Price, Don, Ground Water in the Prineville Area, Crook County, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 1619-P, 1963.

130 Rorabaugh, M.I., Simons, W.D., Garrett, A. A., and McMurtrey, R.G., Exploration of Methods of Relating Ground Water to Surface Water, Columbia River Basin, First Phase, U.S.D.I. Geological Survey Open-File Report, 1962.

131. Rorabaugh, M.I., and Simons, W.D., Exploration of Methods of Relating Ground Water to Surface Water, Columbia River Basin, Second Phase, U.S.D.I. Geological Survey Open-File Report, 1966.

132. Ross, C.P., Andrews, D.A., and Whitkind, I.J., Geologic Map of Montana, U.S.D.I. Geological Survey, 1955.

133. Ross, C.P., and Forrester, J.D., Geologic Map of the State of Idaho, U.S.D.I. Geological Survey Miscellaneous Geologic Investigations Map I-325, 1947.

134. Rothacher, Jack, Streamflow from Small Watersheds on the Western Slope of the Cascade Range, Oregon, American Geophysical Union, Water Resources Research, vol. 1, No. 1, 1965.

135. Russell, I.C., Geology and Water Resources of Nez Perce County, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 53, pt. 1, Geology, p. 1-85, 1901.

136. Russell, I.C., Geology and Water Resources of Nez Perce County, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 54, pt. 2, Water Resources, p. 87-141, 1901.

137. Santos, J.F., Quality of Surface Waters in the Lower Columbia River Basin, U.S.D.I. Geological Survey Water-Supply Paper 1784, 1965.

138. Sceva, J.E., Watkins, F.A., and Schlax, W.N., Geology and Ground-Water Resources of Wenas Creek Valley, Yakima County, Washington, U.S.D.I. Geological Survey Open-File Report, 1949.

139. Sceva, J.E., Preliminary Report of the Ground-Water Resources of Southwestern Skagit County, Washington, U.S.D.I. Geological Survey Open-File Report, 1950.

140. Sceva, J.E., Geology and Ground-Water Resources of Kitsap County, Washington, U.S.D.I. Geological Survey Water-Supply Paper 1413, 1957.

140A. Sceva, J.E., A Reconnaissance of the Ground-Water Resources of the Hood River and the Cascade Locks Area, Hood River County, Oregon, Oregon State Engineer, Ground Water Report No. 10, 1966.

141. Sceva, J.E., A Brief Description of the Ground-Water Conditions in the Ordnance Area, Morrow and Umatilla Counties, Oregon, Oregon State Engineer Ground Water Report 11, 1966.

141A. Sceva, J.E., Liquid Waste Disposal in the Lava Terrane of Central Oregon, FWPCA, April 1968.

142. Sceva, J.E., and Debow, Robert, Ground-Water Levels, 1965, Oregon State Engineer Ground Water Report 9, 1966.

143. Searcy, J.K., Flow Duration Curves (Manual of Hydrology: Part 2, Low-Flow Techniques), U.S.D.I. Geological Survey Water-Supply Paper 1542-A, 1959.

144. Simons, W. D., Concept and Characteristics of Base Flow in the Columbia River Basin, Western Snow Conference Proceedings, p. 57-61, 1953.

145. Smith, G. O., Geology and Water Resources of a Portion of Yakima County, Washington, U.S.D.I. Geological Survey Water-Supply Paper 55, 1901.

146. Smith, R. O., Ground-Water Resources of the Middle Big Wood River-Silver Creek Area, Blaine County, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1478, 1959.

147. Smith, R. O., Geohydrologic Evaluation of Stream-Flow Records in the Big Wood River Basin, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1479, 1960.

148. Stearns, H.T., Geology and Water Resources of the Middle Deschutes River Basin, Oregon, U.S.D.I. Geological Survey Water Supply Paper 637-D, p. 125-220, 1930.

149. Stearns, H. T., Bryan, L. L., and Crandall, Lynn, Geology and Water Resources of the Mud Lake Region, Idaho, Including the Island Park Area, U.S.D.I. Geological Survey Water-Supply Paper 818, 1939.

150. Stearns, H.T., Crandall, Lynn, and Steward, W.G., Geology and Ground-Water Resources of the Snake River Plain in Southeastern Idaho, U.S.D.I. Geological Survey Water-Supply Paper 774, 1938.

151. Stevens, P.R., Ground-Water Problems in the Vicinity of Moscow, Latah County, Idaho, U.S.D.I. Geological Survey Water-Supply 1460-H, p. 325-357, 1960.

152. Stevens, P.R., Effect of Irrigation on Ground Water in Southern Canyon County, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1585, 1962.

153. Stewart, J.W., Water-Yielding Potential of Weathered Crystalline Rocks at the Georgia Nuclear Laboratory, Article 43, U.S.D.I. Geological Survey Professional Paper 450-B, p. 106-107, 1962.

154. Stokes, W. L., Geologic Map of Utah, University of Utah (Salt Lake City), 1963.

155. Sylvester, R.O., and Seabloom, R.W., A Study on the Character and Significance of Irrigation Return Flows in the Yakima River Basin, University of Washington, Department of Civil Engineering (Seattle), 1962.

156. Tagg, K.M., and others, Geologic Map of Nevada in Mineral and Water Resources of Nevada, Senate Document 87, 88th Congress 2nd Session, 1964.

157. Taylor, G. C., Jr., Ground Water in the Quincy Basin, Wahluke Slope and Pasco Slope Subareas of the Columbia Basin Project, Washington, U.S.D.I. Geological Survey Open-File Report, 1948.

158, Theis, C.V., and Conover, C.S., Chart for Determination of the Percentage of Pumped Water Being Diverted from a Stream or Drain, in Shortcuts and Special Problems in Aquifer Tests, U.S.D.I. Geological Survey, Water-Supply Paper 1545-C, 1963.

159. Thomas, C.A., Investigation of the Inflow to the Rathdrum Prairie-Spokane Valley Aquifer, U.S.D.I. Geological Survey Open-File Report, 1963.

160. Trauger, F.D., Basic Ground-Water Data in Lake County, Oregon, U.S.D.I. Geological Survey Open-File Report, 1950.

161. Trauger, F.D., Ground-Water Resources of Baker Valley, Baker County, Oregon, U.S.D.I. Geological Survey Open-File Report, 1950.

162. Trimble, D. E., Geology of Portland, Oregon and Adjacent Areas, U.S.D.I. Geological Survey Bulletin 1119, 1963.

163. U. S. Army, Corps of Engineers, Review of Reports on Columbia River and Tributaries, House Document 531, 8 volumes, 1950.

164. U. S. Army, Corps of Engineers, Interim Report on 1959 Current Measurement Program Columbia River at Mouth, Oregon and Washington, vol. 4, p. 195-292, 1960.

165. U. S. Army, Corps of Engineers, Computer Programs for Summary Hydrograph, 1-3-6-Month Average Flow, Frequency Curve Points, Annual Flow Duration, Monthly Flow Duration, 5-Year Moving Average, and Frequency Curve Statistics, Description Reports for Program Numbers 23001, 23019, 23023, 23024, 23025, 23026, and 23308, 1967.

166. U.S.D.I., Bureau of Reclamation, Snake Plain Recharge Project, Idaho, U.S.D.I. Bureau of Reclamation, Region 1, Special Report, 1962.

167. U.S.D.I. Bureau of Reclamation and U.S. Army Corps of Engineers, Upper Snake River Basin, Preliminary Summary Report, 1960.

168. U.S.D.H.E.W. Public Health Service, Drinking Water Standards, U.S. Public Health Service Publication 956, 1962.

169. Salinity Laboratory Staff, Diagnosis and Improvement of Saline and Alkali Soils, U.S.D.A. Handbook 60, 1954.

170. U.S.D.C. Weather Bureau, Climatic Summary of the United States, Supplement for 1951 Through 1960, Idaho, U.S.D.C. Climatography of the U.S., No. 86-20, 1965.

171. U.S.D.C. Weather Bureau, Climatic Summary of the United States, Supplement for 1951 Through 1960, Montana, U.S.D.C. Climatography of the U.S., No. 86-20, 1965.

172. U.S.D.C. Weather Bureau, Climatic Summary of the United States, Supplement for 1951 Through 1960, Oregon, U.S.D.C. Climatography of the U.S., No. 86-30, 1965.

173. U.S.D.C. Weather Bureau, Climatic Summary of the United States, Supplement for 1951 Through 1960, Washington, U.S.D.C. Climatography of the U.S., No. 86-39, 1965.

174. Van Denburgh, A. S., and Feth, J. H., Solute Erosion and Chloride Balance in Selected River Basins of the Western Conterminous United States, Water Resources Research, vol. 1, No. 4, p. 537-541, 1965.

175. Van Denburgh, A. S., and Santos, J. F., Ground Water in Washington: Its Chemical and Physical Quality, Washington Division of Water Resources Water Supply Bulletin 24, 1965.

176. Van Winkle, W., Quality of Surface Waters of Washington, U.S.D.I. Geological Survey Water-Supply Paper 339, 1914.

177. Van Winkle, W., Quality of Surface Waters of Oregon, U.S.D.I. Geological Survey Water-Supply Paper 363, 1914.

178. Wagner, N. S., Ground Water Studies in Umatilla and Morrow Counties, Oregon Department of Mines and Geology, 1949.

179. Wagner, N. S., "Important Rock Units of Northeastern Oregon," Oregon Department of Geology and Mineral Industries, The Ore Bin, vol. 20, No. 7 (July), 1958.

180. Walker, E.H., The Quality of Ground Water in the Upper Snake River Basin, Washington State University, Institute of Technology (Pullman), Proceedings of Water Quality Conference, November 28-30, p. 79-93, 1960.

181. Walker, E.H., Ground Water in the Midvale and Council Area, Upper Weiser River Basin, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1779-Q, 1964.

182. Walker, E.H., Ground Water in the Sandpoint Region, Bonner County, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1779-I, 1964.

183. Walker, E.H., Ground Water in the Upper Star Valley, Wyoming, U.S.D.I. Geological Survey Water-Supply Paper 1809-C, 1965.

184. Walker, G.W., Reconnaissance Geologic Map of the Eastern Half of the Klamath Falls (AMS) Quadrangle, Lake and Klamath Counties, Oregon, U.S.D.I. Geological Survey Mineral Investigations Field Studies Map MF-260, 1963.

185. Walker, G.W., and others, Geologic Map of Oregon in Mineral and Water Resources of Oregon, Committee on Interior and Insular Affairs, 90th Congress, 2nd Session.

186. Walker, G.W., Peterson, N.V., and Greene, R.C., Reconnaissance Geologic Map of the East Half of the Crescent Quadrangle, Lake, Deschutes, and Crook Counties, Oregon, U.S.D.I. Geological Survey Miscellaneous Geologic Investigations Map I-493, 1967.

187. Walker, G.W., and Repenning, C.A., Reconnaissance Geologic Map of the Adel Quadrangle, Lake, Harney, and Malheur Counties, Oregon, U.S.D.I. Geological Survey Miscellaneous Geologic Investigations Map I-446, 1965.

188. Walker, G.W., and Repenning, C.A., Reconnaissance Geologic Map of the West Half of the Jordan Valley Quadrangle, Malheur County, Oregon, U.S.D.I. Geological Survey Miscellaneous Geologic Investigations Map I-457, 1966.

189. Wallace, E.F., and Molenaar, Dee, Geology and Ground-Water Resources of Thurston County, Washington, Washington Division of Water Resources Water Supply Bulletin 10, vol. 1, 1961.

190. Walters, K.L., Availability of Ground Water at the Border Stations at Laurier and Ferry, Washington, U.S.D.I. Geological Survey Circular 422, 1960.

191. Walters, K.L., and Grolier, M.J., Records of Wells, Water Levels, and Quality of Ground Water in the Columbia Basin Project Area, Washington, Washington Division of Water Resources Water Supply Bulletin 8, 1959.

192. Walton, W.C., Ground-Water Resources of Camas Prairie, Camas and Elmore Counties, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1609, 1960.

193. Waring, G.A., Geology and Water Resources of a Portion of South-Central Oregon, U.S.D.I. Geological Survey Water-Supply Paper 220, 1908.

194. Waring, G.A., Geology and Water Resources of the Harney Basin Region, Oregon, U.S.D.I. Geological Survey Water-Supply Paper 231, 1909.

195. Waring, G.A., Geology and Water Resources of a Portion of South-Central Washington, U.S.D.I. Geological Survey Water-Supply Paper 316, 1913.

196. Waring, G.A., Thermal Springs of the United States and Other Countries of the World--A Summary, U.S.D.I. Geological Survey Professional Paper 492, 1965.

197. Washburn, R.L., Preliminary Investigation of Ground Water in the East Sound Area, Orcas Island, San Juan County, Washington, U.S.D.I. Geological Survey Open-File Report, 1954.

198. Washburn, R.L., Ground Water in the Lummi Indian Reservation, Whatcom County, Washington, U.S.D.I. Geological Survey Open-File Report, 1956.

199. Wegner, D.E., Preliminary Investigation of Ground Water in the Grayland Watershed, Grays Harbor and Pacific Counties Washington, U.S.D.I. Geological Survey Open-File Report, 1956.

200. Weigle, J.M., and Foxworthy, B.L., Geology and Ground-Water Resources of West-Central Lewis County, Washington, Washington Division of Water Resources Water Supply Bulletin 17, 1962.

201. Weigle, J. M., and Mundorff, M.J., Records of Wells, Water Levels and Quality of Ground Water in the Spokane Valley, Spokane County, Washington, U.S.D.I. Geological Survey Open-File Report 1952.

202. Wells, F.G., and Peck, D.L., Geologic Map of Oregon West of the 121st Meridian, U.S.D.I. Geological Survey Miscellaneous Geologic Investigations Map I-325, 1961.

203. West, S.W., and Kilburn, Chabot, Ground Water for Irrigation in Part of the Fort Hall Indian Reservation, Idaho, U.S.D.I. Geological Survey Water-Supply Paper 1576-D, 1963.

204. Williams, R.C., and Stevens, H.H., Jr., Sediment Transport in Oregon and Idaho for Flood of December 1964, Report of Meeting on Erosion and Sedimentation, 1964-65 Flood Season, Columbia Basin Inter-Agency Committee, p. 23-35, 1965.

205. Wolfe, J.W., Effect of Controlled River Level on Field of Irrigation Wells near Jefferson, Oregon, Oregon State College Agricultural Experiment Station (Corvallis) Miscellaneous Paper 84, 1959.

206. Young, R.A., Hydrogeologic Evaluation of the Streamflow Records in the Rogue River Basin, Oregon, U.S.D.I. Geological Survey Open-File Report, 1961.

GLOSSARY

ACRE-FOOT (ac-ft) - A unit commonly used for measuring the volume of water or sediment; equal to the quantity of water required to cover one acre to a depth of one foot and equal to 43,560 cubic feet or 325,851 gallons.

ANNUAL FLOOD SERIES - A list of annual floods.

AQUIFER - A rock formation, bed, or zone containing water that is available to wells. An aquifer may be referred to as a water-bearing formation or water-bearing bed.

AREA-CAPACITY CURVES - A graph showing the relation between elevation and (1) surface area of the water in a reservoir and (2) volume.

ARTESIAN WATER - Ground water under sufficient pressure to rise above the level at which the water-bearing bed is reached in a well. The pressure in such an aquifer commonly is called artesian pressure, and the rock containing artesian water is an artesian aquifer.

BANK STORAGE - The water absorbed into the banks of a stream, lake, or reservoir, when the stage rises above the water table in the bank formations, then returns to the channel as effluent seepage when the stage falls below the water table.

BASE FLOW - See Base Runoff.

BASE RUNOFF - Sustained or fair weather runoff. In most streams, base runoff is composed largely of ground-water effluent. The term base flow is often used in the same sense as base runoff. However, the distinction is the same as that between streamflow and runoff. When the concept in the terms base flow and base runoff is that of the natural flow in a stream, base runoff is the logical term.

CHANNEL STORAGE - The volume of water at a given time in the channel or over the flood plain of the streams in a drainage basin or river reach. Channel storage is sometimes significant during the progress of a flood event.

CONE OF DEPRESSION - A cone-like depression of the water table or other piezometric surface that is formed in the vicinity of a well by withdrawal of water. The surface area included in the cone is known as the area of influence of the well.

CONFINED WATER (ARTESIAN) - Water under artesian pressure. Water that is not confined is said to be under water table conditions.

CONSUMPTIVE USE - The quantity of water discharged to the atmosphere or incorporated in the products in the process of vegetative growth, food processing, industrial processes, or other use.

CONSUMPTIVE USE, IRRIGATION - The quantity of water that is absorbed by the crop and transpired or used directly in the building of plant tissue, together with that evaporated from the cropped area.

CONSUMPTIVE USE REQUIREMENT (CROP) - The annual irrigation consumptive use expressed in feet or acre-feet per acre.

CONSUMPTIVE USE REQUIREMENT ANNUAL DISTRIBUTION - The percentage of consumptive use required by months.

CONSUMPTIVE WASTE - The water that returns to the atmosphere without benefiting man.

COOLING WATER CONSUMPTION (POWER) - The cooling water which is lost to the atmosphere, caused primarily by evaporation due to the temperature rise in the cooling water as it passes through the condenser. The amount of consumption (loss) is dependent on the type of cooling employed--flow-through, cooling pond, or cooling tower.

COOLING WATER REQUIRED (POWER) - The amount of water needed to pass through the condensing unit in order to condense the steam to water.

CORRELATION - The process of establishing a relation between two or more related variables. It is a simple correlation if there is only one independent variable; multiple correlation if there is more than one independent variable.

CORRELATIVE ESTIMATES - A value determined by correlation.

CUBIC FEET PER SECOND (cfs) - A unit expressing rate of discharge. One cubic foot per second is equal to the discharge of a stream having a cross section of one square foot and flowing at an average velocity of one foot per second. It also equals a rate of 448.8 gallons per minute. It is also known in storage terms as a second-foot-day (sfd).

CUBIC FEET PER SECOND PER DAY (cfs-day) - The volume of water represented by a flow of one cubic foot per second for 24 hours. It equals 86,400 cubic feet, 1.983471 acre-feet, or 646,317 gallons.

DEPLETION (WATER) - That portion of water supply that is consumptively used.

DEPLETION, STREAMFLOW - The amount of water that flows into a valley, or onto a particular land area, minus the water that flows out of the valley or off from the particular land area.

DEPRESSION STORAGE - Water contained in natural depressions in the land surface, such as puddles.

DISCHARGE - In its simplest concept, discharge means outflow; therefore, the use of this term is not restricted as to course or location and it can be used to describe the flow of water from a pipe or a drainage basin.

DISCHARGE, AVERAGE - The arithmetic average of the annual discharges for all complete water years of record whether or not they are consecutive. The term "average" is generally reserved for average of record and "mean" is used for averages of shorter periods; namely, daily mean discharge.

DIVERSION - The taking of water from a stream or other body of water into a canal, pipe, or other conduit.

DRAINAGE AREA - The drainage area of a stream, measured in a horizontal plane, which is enclosed by a drainage divide.

DRAINAGE BASIN - A part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

DRAINAGE DIVIDE - The line of highest elevations which separates adjoining drainage basins.

DRAWDOWN (GROUND WATER) - The depression or decline of the water level in a pumped well or in nearby wells caused by pumping. It is the vertical distance between the static and the pumping level at the well.

DROUGHT - A period of deficient precipitation or runoff extending over an indefinite number of days, but with no set standard by which to determine the amount of deficiency needed to constitute a drought. Thus, there is no universally accepted quantitative definition of drought; generally, each investigator establishes his own definition.

EFFECTIVE PRECIPITATION - That part of the precipitation falling on a crop area that is effective in meeting the consumptive use requirements of the crop.

EROSION, BANK - Destruction of land areas bordering rivers or water bodies by the cutting or wearing action of waves or flowing water.

EROSION, BEACH - The retrogression of the shore line of large lakes and coastal waters caused by wave action, shore currents, or natural causes other than subsidence.

EROSION, GULLY - The widening, deepening, and headcutting of small channels and waterways due to erosion.

EVAPORATION, NET RESERVOIR - The evaporative water loss from a reservoir after making allowance for precipitation on the reservoir and runoff that would have occurred from that precipitation from the land area covered by the reservoir. Net reservoir evaporation equals the total evaporation minus the precipitation on the reservoir plus the runoff from the land area covered by the reservoir.

EVAPORATION PAN - An open tank used to contain water for measuring the amount of evaporation. The U.S.D.C. Weather Bureau class A pan is 4 feet in diameter, 10 inches deep, set up on a timber grillage so that the top rim is about 16 inches from the ground. The water level in the pan during the course of observation is maintained between 2 and 3 inches below the rim.

EVAPORATION PAN COEFFICIENT - The ratio of evaporation from a large body of water to that from an evaporation pan.

EVAPOTRANSPIRATION - The combined losses of evaporation of water and transpiration by plants. Evapotranspiration is often limited by the quantity of water available. A commonly used term is potential evapotranspiration which is the maximum amount of moisture that, if continuously available, would be removed from the soil under existing conditions of humidity, wind movement, and temperature.

EXCEEDENCE FREQUENCY - Percent of values that exceed a specified magnitude.

FARM WASTE AND DEEP PERCOLATION - The amount of irrigation water delivered to the crop area from a canal turnout or ground water pump that is not consumptively used on the crop area. Includes water moving through the root zone to the water table, water intercepted by drainage systems, and surface waste to natural or constructed drainage systems, and noncropped areas.

FIELD MOISTURE CAPACITY - The quantity of water which can be permanently retained in the soil in opposition to the downward pull of gravity.

FLOOD - Any relatively high streamflow or an overflow or inundation that comes from a river or other body of water and causes or threatens damage.

FLOOD, ANNUAL - The highest peak discharge in a water year.

FLOOD DURATION CURVE - A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.

FLOOD FREQUENCY CURVE - A graph showing the number of times per 100 years, or the average interval of times within which a flood of a given magnitude will be equaled or exceeded.

FLOOD PEAK - The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge. Flood crest has nearly the same meaning but, since it connotes the top of the flood wave, it is properly used only in referring to stage.

FLOOD PLAIN - A strip of relatively smooth land bordering a stream that has been or is subject to flooding. It is called a "living" flood plain if it is overflowed in times of high water, but a "fossil" flood plain if it is beyond the reach of the highest flood.

FLOOD, PROBABLE MAXIMUM - The largest flood for which there is any reasonable expectancy in the geographical region involved.

FLOOD ROUTING - The process of determining progressively downstream the timing and stage of a flood at successive points along a river.

FLOOD STAGE - The stage at which overflow of the natural banks of a stream begins to cause damage in the reach in which the stage is observed.

FLOOD, STANDARD PROJECT - A hypothetical flood that might result from the most severe combination of meteorological and hydrological conditions that are reasonably characteristic of the geographical region involved. The SPF is the usual basis for design of flood control structures.

FLOODWAY - The channel of a river or stream and those parts of the flood plains adjoining the channel which carry and discharge the floodwater or floodflow of any river or stream.

FLOW DURATION CURVE - A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.

FLOWING WELL - An artesian well having sufficient head to discharge water above the land surface.

FREEBOARD - The vertical distance between a design maximum water level and the top of a structure. This space is utilized for safety.

GAGING STATION - A particular site on a stream, canal, lake, or reservoir where systematic observations or gage height or discharge are obtained.

GAGING STATION NUMBER - An eight-digit number assigned to a gaging station which identifies the station in downstream order relative to other gaging stations and sites where streamflow data are collected. The first two digits designate the major drainage basin, the others the station.

GROUND WATER - Water in the ground that is in the zone of saturation from which wells, springs, and ground-water runoff are supplied.

GROUND WATER OUTFLOW - That part of the discharge from a drainage basin that occurs through the ground water. The term "underflow" is often used to describe the ground water outflow that takes place in valley alluvium (instead of the surface channel) and thus is not measured at a gaging station.

HIGH FLOW VOLUME - Highest mean discharge for a specified period of time.

HIGH FLOW VOLUME FREQUENCY CURVES - Graphical representation of the high flow volume frequency distribution.

HYDRAULIC GRADIENT (GROUND WATER) - The gradient or slope of the water table or piezometric surface in the direction of the greatest slope, generally expressed in feet per mile.

HYDROGRAPH - A graph showing stage, flow, velocity, or other property of water with respect to time.

HYDROLOGIC BUDGET - An accounting of the inflow, outflow, and storage in a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, reservoir, or irrigation project.

HYDROLOGIC CYCLE - A term denoting the circulation of water from the sea, through the atmosphere, to the land; and, thence, with many delays, back to the sea by overland and subterranean routes, and,in part, by way of the atmosphere without reaching the sea.

INFILTRATION - The flow of a fluid into a substance through pores or small openings. It connotes flow into a substance in contradistinction to the word percolation, which connotes flow through a porous substance.

INFILTRATION CAPACITY - The maximum rate at which the soil, when in a given condition, can absorb falling rain or melting snow.

INTERCEPTION (HYDROLOGY) - The process of storing rain or snow on leaves and branches which eventually evaporates back to the air. Interception equals the precipitation on the vegetation minus streamflow and throughfall.

INTERSTICES - The openings or pore spaces in a rock. In the zone of saturation they are filled with water.

IRRIGATED AREA - The gross farm area upon which water is artificially applied.

IRRIGATION CONVEYANCE LOSS AND WASTE - The loss of water in transit from a reservoir, point of diversion, or ground-water pump (if not on farm) to the point of use, whether in natural channels or in artificial ones, such as canals, ditches, and laterals.

IRRIGATION DELIVERY REQUIREMENT, FARM - The amount of water in acre-feet per acre required to serve the irrigated area. It is the crop irrigation requirement plus farm waste and deep percolation.

IRRIGATION DEPLETION - The amount of diverted water consumptively used, beneficially and nonbeneficially, in serving a cropped area. It is the gross diversion minus return flow.

IRRIGATION EFFICIENCY - The percentage of water applied that can be accounted for in soil moisture increase.

IRRIGATION REQUIREMENT, CROP - The amount of irrigation water in acre-feet per acre required by the crop; it is the difference between crop consumptive use requirement and effective precipitation.

ISOHYETAL LINE - A line drawn on a map or chart joining points that receive the same amount of precipitation.

LEACHING REQUIREMENT - The amount of water required to move residual salts out of the root zone and maintain an adequate soil-salt balance for crop production.

LOW FLOW FREQUENCY CURVE - A graph showing the magnitude and frequency of minimum flows for a period of given length. Frequency is usually expressed as the average interval, in years, between recurrences of an annual minimum flow equal to, or less than, that shown by the magnitude scale.

MAXIMUM WATER SURFACE (RESERVOIR) - The maximum water-surface elevation is the highest water surface elevation for which the dam is designed. It is also the top of the surcharge capacity.

NORMAL ANNUAL PRECIPITATION - Average annual precipitation during the base period, 1931-1960 inclusive.

PAN EVAPORATION - Evaporation in inches from a standard Weather Bureau class A pan.

PARTIAL DURATION FLOOD SERIES - A list of all flood peaks that exceed a chosen base stage or discharge.

PERCHED WATER - Ground water separated from the underlying water table by a zone of impervious or relatively impervious material.

PERCOLATION - The movement, under hydrostatic pressure, of water through the interstices of a rock or soil.

PERCOLATION, DEEP - The amount of water that passes below the root zone of the crop or vegetation.

PERMEABILITY - The capacity of an aquifer to transmit water. The field coefficient of permeability of an aquifer is the coefficient of transmissability divided by the saturated thickness of the aquifer, in feet.

PIEZOMETRIC SURFACE - An imaginary surface that everywhere coincides with the static level of the water in the aquifer.

POROSITY - Porosity is the property of containing openings or interstices. In rock or soil, it is the ratio (usually expressed as a percentage) of the volume of openings in that material to the bulk volume of the material.

PRECIPITATION - As used in hydrology, precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface. It is the common process by which atmospheric water becomes surface or subsurface water. The term "precipitation" is also commonly used to designate the quantity of water that is precipitated.

RAINFALL - The quantity of water that falls as rain. Not synonymous with precipitation.

RECHARGE (GROUND WATER) - The addition of water to the zone of saturation. Infiltration of precipitation and its movement to the water table is one form of natural recharge; injection of water into an aquifer through wells is one form of artificial recharge.

RECURRENCE INTERVAL - The average number of years within which a given event will be equaled or exceeded.

RESERVOIR - A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

RESERVOIR, MULTIPLE-PURPOSE - A reservoir planned to serve more than one purpose.

RESERVOIR, RE-REGULATING - A reservoir used to regulate the outflow from an upstream reservoir.

RESERVOIR, RETARDING - Ungated reservoir for temporary storage of floodwater. Sometimes called a detention reservoir.

RESERVOIR, SINGLE-PURPOSE - A reservoir planned to serve only one purpose.

RETURN FLOW (IRRIGATION) - Irrigation water applied to an area which is not consumed in evaporation or transpiration and returns to a surface stream or ground-water aquifer.

RIPARIAN - Pertaining to the banks of streams, lakes, or tidewater.

RIVER REACH - Any defined length of a river.

RUNOFF - That part of the precipitation that appears in surface streams. It is the same as streamflow unaffected by artificial diversions, storage or other works of man in or on the stream channels.

RUNOFF, ADJUSTED MEAN ANNUAL - Average annual runoff adjusted for length of record by comparison with record at pivot stations.

RUNOFF, AVERAGE ANNUAL - Average of water year runoff in inches or acre-feet for the total period of record.

SEDIMENT - Fragmental or clastic mineral particles derived from soil, alluvial, and rock materials by processes of erosion; and transported by water, wind, ice, and gravity. A special kind of sediment is generated by precipitation of solids from solution (i.e., calcium carbonate, iron oxides). Excluded from the definition are vegetation, wood, bacterial and algal slimes. extraneous light-weight artificially made substances such as trash, plastics, flue ash, dyes, and semisolids.

SEDIMENT DISCHARGE - The rate at which dry weight of sediment passes a section of a stream or the quantity of sediment, as measured by dry weight or by volume, that is discharged in a given time.

SOIL MOISTURE - Water diffused in the soil, the upper part of the zone of aeration from which water is discharged by the transpiration of plants or by soil evaporation.

SPECIFIC CAPACITY - The yield of a well per unit of drawdown after a specified period of pumping. Generally expressed as gallons per minute (gpm) per foot of drawdown.

SPECIFIC YIELD (GROUND WATER) - The ratio of the volume of water that a rock will yield by gravity, after being saturated, to its own volume, expressed as a percentage.

STATIC LEVEL (GROUND WATER) - The level of water in a nonpumping or nonflowing well. For the purpose of computing the drawdown, it generally is the water level immediately before pumping begins.

STORAGE - Water naturally or artificially impounded in surface or underground reservoirs.

STORAGE CAPACITY, ACTIVE (USABLE) - The volume normally available for release from a reservoir below the stage of the maximum controllable level. (Total capacity less inactive and dead capacity).

STORAGE CAPACITY, CONSERVATION - Storage capacity available for all useful purposes such as municipal water supply, power, irrigation, recreation, fish and wildlife, etc., excluding joint use and exclusive flood control capacity.

STORAGE CAPACITY, DEAD - The volume of a reservoir below the sill or invert of the lowest outlet.

STORAGE CAPACITY, EXCLUSIVE FLOOD CONTROL - The space in reservoirs reserved for the sole purpose of regulating flood inflows to abate flood damage.

STORAGE CAPACITY, INACTIVE - The portion of live storage capacity from which water normally will not be withdrawn, in compliance with operating agreements or restrictions.

STORAGE CAPACITY, JOINT USE - The volume of a reservoir available to store water jointly for flood control and conservation purposes.

STORAGE CAPACITY, LIVE - The volume of a reservoir exclusive of dead and surcharge storage capacity.

STORAGE CAPACITY SEDIMENT - The volume of a reservoir planned for the deposition of sediment.

STORAGE CAPACITY, SURCHARGE - The volume of a reservoir between the maximum water surface elevation for which the dam is designed and the crest of an uncontrolled spillway, or the normal full-pool elevation with the crest gates in the normal closed position.

STORAGE CAPACITY, TOTAL - The total volume of a reservoir exclusive of surcharge.

STORAGE COEFFICIENT (GROUND WATER) - The volume of water released from storage or taken into storage in an aquifer per unit surface area of the aquifer per unit change in the component of head perpendicular to that surface.

STREAM - A general term for a body of flowing water. In hydrology, the term is generally applied to the water flowing in a natural channel as distinct from a canal. More generally, as in the term stream gaging, it is applied to the water flowing in any channel, natural or artificial.

STREAM, EFFLUENT - A stream or reach of stream fed by ground water. It is also called a gaining stream.

STREAM, EPHEMERAL - A stream that flows only in response to precipitation.

STREAM, INFLUENT - A stream that contributes water to the zone of saturation.

STREAM, INTERMITTENT - A stream that flows only part of the time or through only part of its reach.

STREAM, PERENNIAL - A stream that flows continuously.

STREAMFLOW - The discharge that occurs in a natural channel. Although the term discharge can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. Streamflow is a more general term than runoff, as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

STREAMFLOW REGULATION - The artificial manipulation of the flow of a stream.

SUPPLEMENTAL IRRIGATION - When irrigation water supplies are obtained from more than one source, the source furnishing the initial supply is commonly designated the primary source, and the sources furnishing the additional supplies, the supplemental sources.

TRANSMISSIBILITY (GROUND WATER) - The capacity of a rock to transmit water under pressure. The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer one foot wide, extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. Hydraulic gradient of 100 percent means a one foot drop in head in one foot of flow distance.

WATERSHED - A term to signify drainage basin or catchment area.

WATER TABLE - The upper surface of a zone of saturation. No water table exists where that surface is formed by an impermeable body.

WATER YEAR - The 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends.

WATER YIELD - Runoff, including ground-water outflow that appears in the stream, plus ground-water outflow that leaves the basin underground. Water yield is the precipitation minus the evapotranspiration.

PARTICIPATING STATES AND AGENCIES

STATES

Idaho	Nevada	Utah	Wyoming
Montana	Oregon	Washington	

FEDERAL AGENCIES

Department of Agriculture
- Economic Research Service
- Forest Service
- Soil Conservation

Department of the Army
- Corps of Engineers

Department of Commerce
- Economic Development Administration
- Weather Bureau

Dept. of Health, Education, & Welfare
- Public Health Service

Dept. of Housing & Urban Development

Dept. of Transportation

Department of the Interior
- Bonneville Power Administration
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Bureau of Outdoor Recreation
- Bureau of Reclamation
- Fed. Water Pollution Control Adm.
- Fish and Wildlife Service
- Geological Survey
- National Park Service

Department of Labor

Federal Power Commission